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Energy Landscapes: Coal Canals, Oil Pipelines, Electricity Transmission Wires in the Mid-atlantic, 1820-1930

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Abstract

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Energy Landscapes integrates history of technology, environmental history, and business history to provide new perspectives on how Americans began to use fossil fuels and the social implications of these practices. First, I argue that the development of transport infrastructure played critical, and underappreciated, roles in shaping social energy choices. Rather than simply responding passively to the needs of producers and consumers, canals, pipelines, and wires structured how, when, where, and in what quantities energy was used. Second, I analyze the ways fossil fuel consumption transformed the society, economy, and environment of the mid-Atlantic. I link the consumption of coal, oil, and electricity to the development of an urban and industrialized region, the transition from an organic to a mineral economy, and the creation of a society dependent on fossil fuel energy.

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TRANSMISSION WIRES IN THE MID-ATLANTIC, 1820-1930

Christopher F. Jones

A DISSERTATION

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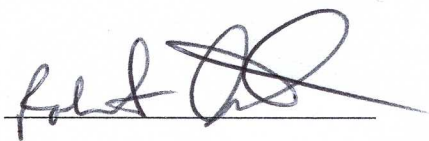
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A handwritten signature in dark ink, reading "Ruth Schwartz Cowan", written over a horizontal line.

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Graduate Group Chairperson

Energy Landscapes: Coal Canals, Oil Pipelines, and Electricity Transmission
Wires in the Mid-Atlantic, 1820-1930

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Christopher F. Jones

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Abstract

ENERGY LANDSCAPES: COAL CANALS, OIL PIPELINES, AND ELECTRICITY
TRANSMISSION WIRES IN THE MID-ATLANTIC, 1820-1930

Christopher Jones

Ruth Schwartz Cowan

Coal canals, oil pipelines, and electricity transmission wires transformed the built environment of the American mid-Atlantic region between 1820 and 1930. By transporting coal, oil, and electrons cheaply, reliably, and in great quantities, these technologies reshaped the energy choices available to mid-Atlantic residents. In particular, canals, pipelines, and wires created new energy landscapes: systems of transport infrastructure that enabled the ever-increasing consumption of fossil fuels.

Energy Landscapes integrates history of technology, environmental history, and business history to provide new perspectives on how Americans began to use fossil fuels and the social implications of these practices. First, I argue that the development of transport infrastructure played critical, and underappreciated, roles in shaping social energy choices. Rather than simply responding passively to the needs of producers and consumers, canals, pipelines, and wires structured how, when, where, and in what quantities energy was used. Second, I analyze the ways fossil fuel consumption transformed the society, economy, and environment of the mid-Atlantic. I link the consumption of coal, oil, and electricity to the development of an urban and industrialized region, the transition from an organic to a mineral economy, and the creation of a society dependent on fossil fuel energy.

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Introduction

Coal canals, oil pipelines, and electricity transmission wires transformed the built environment of the American mid-Atlantic between 1820 and 1930. By connecting rural sites of energy abundance with urban consumption centers, canals, pipelines, and wires created new energy landscapes: infrastructure networks that enabled fossil fuel energy to be transported cheaply, reliably, and abundantly. The ever-increasing consumption of coal, oil, and electricity made possible by these technologies, in turn, led to the development of an urban and industrialized region, the transition from an organic to a mineral economy, and the creation of a society dependent on fossil fuel energy.

Consider the difference between life in the mid-Atlantic in 1820 and in 1930. In 1820, most people in the mid-Atlantic lived in rural areas and worked on farms. Philadelphia and New York City, the region's leading cities, were commercial trade centers with tens of thousands of residents. Manufacturing was a small part of the overall economy, mostly clustered in areas where falling streams powered mills and machinery. Muscles—human and animal—supplied most of the society's energy needs while firewood provided heat for homes, cooking, and industry.

By 1930, most people in the mid-Atlantic lived in cities and many worked in factories. Philadelphia and New York had grown into sprawling metropolitan centers with millions of residents.¹ While agriculture and commerce remained important, industry was the most dynamic and rapidly growing sector of the economy. The

¹ In 1820, Philadelphia had 63,802 residents and New York City had a population of 125,706. In 1930, Philadelphia had 1,950,961 residents and New York City had 6,930,446 people. John Andriot, *Population Abstract of the United States* (McLean, Va.: Andriot Associates, 1980).

geography of industry had shifted as well; most factories were now located in large cities. Mid-Atlantic residents used fossil fuels to heat their homes, power factories, transport goods, and travel between places.

The cheap and abundant transport of coal, oil, and electricity by canals, pipelines, and wires structured these developments. Moreover, the new energy practices that emerged between 1820 and 1930 shaped broad changes in the mid-Atlantic and the rest of the nation. Urbanization created new living patterns and exacerbated class segregation. Industrialization altered the experience of work for factory employees, transforming training patterns and skill sets, relations between workers and employees, and the organization of labor. The rise of urban factories led to concentrated flows of people from Europe into New York and Philadelphia. The proliferation of large corporations involved in the production and transport of fossil fuels influenced the nation's political responses to the rise of monopoly capital. Fossil fuels initiated new leisure practices including driving automobiles for pleasure and using electric technologies like phonographs and movie projectors. In short, many aspects of how people lived, worked, and played were affected by the development of a fossil fuel-intensive society in the mid-Atlantic.

Energy Landscapes analyzes the energy history of the American mid-Atlantic from 1820 to 1930. I link the development of transport technologies to the new energy practices they made possible and show how these changes impacted economic opportunities, residential living patterns, factory locations, and leisure activities. Ultimately, fossil fuels helped transform the mid-Atlantic region from a commercial and

agricultural node in a mercantile network into an urban and industrialized society at the heart of the United States' emergence as a global military and economic superpower.

In this work, I seek to contribute to debates about how Americans came to use new energy sources and the social implications of fossil fuel consumption. Three aspects of my approach are particularly important. First, I highlight the role of energy transport infrastructure. Existing literature focuses on the production of energy and largely treats canals, pipelines, and wires as afterthoughts responding passively to the needs of producers and consumers.² This view is too limited. *Energy Landscapes* demonstrates that canals, pipelines, and wires structured how, when, where, and in what quantities mineral energy sources were used. Decisions about where these technologies would be built, who would own them, and how they would be operated shaped the actions of energy producers and consumers, encouraged the widespread adoption of new energy sources, and redirected the development patterns of the entire region.

Second, I use the concept of the shift from the organic to the mineral economy to analyze the social effects of new energy consumption practices. This theoretical framework provides a particularly effective way to understand the broader implications of fossil fuel consumption and the energy history of the mid-Atlantic. For example, it

² No single work focuses on the transportation of coal, oil, and electricity in the mid-Atlantic. In general, these industries have been studied separately and from the perspective of production. Some of the better industry analyses touch on transport matters but do not make it their primary focus: Donald L. Miller and Richard E. Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields* (Philadelphia: University of Pennsylvania Press, 1985); Harold Francis Williamson and Arnold Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899* (Westport, Conn.: Greenwood Press, 1959); Richard F. Hirsh, *Technology and Transformation in the American Electric Utility Industry* (Cambridge; New York: Cambridge University Press, 1989). There is a much smaller literature that addresses the transport of individual energy sources: Chester Lloyd Jones, *The Economic History of the Anthracite-Tidewater Canals* (Philadelphia: University of Pennsylvania Press, 1908); Arthur Menzies Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906" (Thesis, Vanderbilt University. Published for the American Historical Association by Cornell University Press, 1956); Thomas Parke Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).

illuminates the ways processes like urbanization and industrialization depend on energy transitions. My research also enriches our understanding of this framework. This is the first study to focus on the interrelationships between energy transport infrastructure and the development of the mineral economy. Moreover, while this framework has been developed mainly through studies of Britain and to a certain extent Germany, I know of only one other study of organic and mineral economies in the American context.³

Third, I focus on the mid-Atlantic, America's first region to use fossil fuels intensively. Mid-Atlantic residents pioneered the large-scale construction of transport infrastructure and the region's boosters played crucial roles in establishing new energy consumption practices. Over time, the patterns of the mid-Atlantic extended beyond its boundaries. Many other regions saw the economic benefits of fossil fuel consumption and sought to emulate the example of the mid-Atlantic. I also study the mid-Atlantic because there are methodological benefits to regional analysis. The most important is that regions can provide a middle-level for analysis that strikes a balance between a unit that may be too unwieldy to examine in depth (such as the nation-state) and one that may be too local to produce insights that are broadly applicable (such as a particular community). Regions offer the possibility of studying widespread energy practices while retaining a sense of local particularities.⁴

³ Thomas G. Andrews, *Killing for Coal: America's Deadliest Labor War* (Cambridge, MA: Harvard University Press, 2008).

⁴ Good examples of regional analyses include: William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W. W. Norton, 1991); John C. Hudson, *Making the Corn Belt: A Geographical History of Middle-Western Agriculture* (Bloomington: Indiana University Press, 1994); Richard White, *The Organic Machine* (New York: Hill and Wang, 1995).

Thematics

Transport Infrastructure & Energy Landscapes

Coal canals, oil pipelines, and electricity transmission wires are energy transport infrastructure systems that created new energy landscapes in the mid-Atlantic region between 1820 and 1930. Let me unpack this statement by explaining what I mean by infrastructure and energy landscapes.

Infrastructure

Infrastructure is a particular type of technology. While historians of technology have devoted significant attention to large technical systems, there has been relatively little explicit analysis of the distinctive features of infrastructure.⁵ Although infrastructure may belong to the same family as other technologies, they are not members of the same genus. In particular, infrastructure systems are highly capital-intensive, structure human activities according to their designs, last a long time, yet have a remarkable ability to remain socially invisible.

First, infrastructure projects are typically very expensive. Canals built during the antebellum era were among the most capital-intensive undertakings of the time. Oil pipelines and electricity transmission wires were somewhat cheaper comparatively, but still cost the equivalent of millions of dollars if the expenditures are adjusted to present-day values. The high cost of infrastructure has several implications. Building

⁵ Examples of the large technical system literature include: Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*; Arne Kaijser and Erik van der Vleuten, eds., *Networking Europe: Transnational Infrastructures and the Shaping of Europe, 1850-2000* (Sagamore Beach, MA: Science History Publications, 2006). One work studying infrastructure more explicitly is Paul N. Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," in *Modernity and Technology*, ed. Thomas J. Misa, Philip Brey, and Andrew Feenberg (Cambridge, MA: The MIT Press, 2003).

infrastructure requires lots of investors and/or a large organization to pay for, construct, and manage the system. In practice, this usually means that the state plays a prominent role by building the infrastructure itself or granting privileges like corporate charters and rights to land. It is unlikely that small, decentralized efforts can produce infrastructure. In addition, the high capital costs of infrastructure create disincentives for the building of competing systems. Once a society has invested significant resources into one type of infrastructure, it is much harder to justify the expense of a parallel or replacement system. In other words, a choice to do things one way usually initiates a path-dependent trajectory that is difficult to break.⁶

Second, infrastructure systems encourage certain types of activity. At the most basic level, infrastructure makes certain things easier to do. Bruno Latour offers a few straightforward examples of how technologies shape people's actions.⁷ He notes that people have a tendency to leave doors open when they exit a room and to drive without wearing a seatbelt. One option for changing these unwanted behaviors is education: teaching people about opening and closing doors and wearing seatbelts. However, this involves a lot of effort and there is no guarantee that it will work. On the other hand, designing technologies that make it difficult to engage in these behaviors can be an easier and more effective strategy. Self-closing doors and automatic seatbelts can alter unwanted behavior much more simply, because it means a person must exert more effort

⁶ Such transitions do happen—witness the transfer of coal from canals to railroads and crude oil from railroads to pipelines—but they are comparatively rare and require the significant allocation of resources.

⁷ Bruno Latour, "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts," in *Shaping Technology / Building Society: Studies in Sociotechnical Change*, ed. Wiebe E. Bijker and John Law (Cambridge, MA: The MIT Press, 1992).

not to shut the door or put on a seat belt. People tend to take the path of least resistance, and technologies can make certain things easy and other things hard.⁸

Infrastructure operates in this way, only at a much bigger scale. This has important implications for our understanding of canals, pipelines, and wires. Each of these technologies alters social energy practices by changing the path of least resistance. For example, without canals, it was difficult and expensive to ship anthracite coal from northeast Pennsylvania to Philadelphia. It was easier and cheaper for residents of the Quaker City to use imported coal from Britain or firewood. Once several canals were built, the cost of anthracite dropped dramatically and it could be delivered in large quantities. This change in supply and price altered the social logic of coal consumption. By making coal cheap and abundant, canals made anthracite consumption the path of least resistance for Philadelphia's residents. Canals, pipelines, and wires, therefore, can have the consequence of encouraging the consumption of fossil fuels.

Third, infrastructure is distinctive because of its durability. Canals, pipelines, and wires are built to last a long time. Therefore, these technologies are not only significant at the date of their completion; they will matter for the next several decades. If a company builds an oil pipeline in year one, it is committing itself to transporting oil in year ten, twenty, thirty, and forty. Since canals, pipelines, and wires also have the effect of encouraging the consumption of energy as seen above, the durability of infrastructure means that they reinforce these patterns for several decades.

⁸ Cass Sunstein and Richard Thaler have recently applied the logic of shaping outcomes through creating a path of least resistance to public policy more generally: Richard H. Thaler and Cass R. Sunstein, *Nudge: Improving Decisions About Health, Wealth, and Happiness* (New Haven: Yale University Press, 2008).

Finally, infrastructure is remarkably invisible. Infrastructure projects are typically massive, involve huge expenditures of capital, materials, and expertise, and transform the built environment. Our daily lives are dependent upon the smooth operations of these systems, whether it is the transport networks that enable the flows of people and goods, sewage systems that remove and process our waste, or electrical grids that power everything from laptops to household appliances to security systems. Life as we know it could not exist without infrastructure. But despite the importance of infrastructure to society, it is not given the explicit level of attention by politicians, citizens, and scholars that it would seem to warrant. Only in times of crisis—electricity blackouts or threats by Russia to cut off natural gas supplies to Europe—does public perception of infrastructure get heightened. Once constructed, infrastructure tends to be quickly naturalized. The fact that infrastructure derives comparatively little social notice is peculiar and worth studying further.

Collectively, these features of infrastructure indicate that canals, pipelines, and wires are capital-intensive technologies that encourage the consumption of fossil fuel energy over long periods of time in a relatively invisible manner.

Energy Landscapes

I argue throughout this work that canals, pipelines, and wires created new energy landscapes: systems of energy transport infrastructure in action in a regional and social context. Energy landscapes have several characteristics. First, they have a physical dimension. At base, an energy landscape includes an infrastructure system or systems (such as canals, pipelines, and wires) and the energy source or sources (such as wood,

coal, or oil) to be transported. Second, energy landscapes are rooted in particular places. They have a specific geography that includes some areas but not others. Third, energy landscapes are dynamic systems based on the flow of energy resources. Without flow, there is no energy landscape. Finally, energy landscapes include the social context in which these systems operate. A society's economic, cultural, political, and environmental beliefs shape the ways energy landscapes function and their social effects.⁹

I use the concept of energy landscapes to analyze transport infrastructure in a dynamic, regional, and social context. I find it useful to think in terms of energy landscapes because it focuses our attention on issues that might get lost in the study of a single canal, pipeline, or wire, such as the synergistic properties of these networks, the geography of energy, and technologies in use. In other words, thinking about energy landscapes helps us ask and answer new questions.

First, the concept of energy landscapes encourages us to analyze the collaborative effects of transport infrastructure systems. When canals, pipelines, and wires have been studied, it has often been with an eye towards understanding the rivalries between competing shippers. These conflicts are important, because they shape how these technologies are built and whom they benefit.¹⁰ However, an exclusive focus on inter-corporate rivalries misses the synergistic effects of canals, pipes, and wires. The owners

⁹ Although this dissertation discusses energy landscapes in the context of mineral economies, they are not limited to societies consuming fossil fuels. The organic economy has energy landscapes as well—they just happen to have different technologies, energy sources, flow patterns, and regional scales, thereby establishing different relationships between humans and the environment.

¹⁰ Most of the literature on transport infrastructure, particularly from the perspective of business and economic history, emphasizes the rivalries between competing shippers. In Chapters 1, 3, and 5, I draw on this literature because it is an important starting point for understanding these systems. Detailed references to such works are available in these chapters. A few examples include: Jones, *The Economic History of the Anthracite-Tidewater Canals*; Rolland Harper Maybee, *Railroad Competition and the Oil Trade, 1855-1873* (Mt. Pleasant, Mich.: The Extension Press, 1940); Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906".

of the companies that built these technologies all sought to increase energy demand by developing new applications for coal, oil, and electricity. Consumers felt more confident switching to new energy sources when the presence of multiple shippers made the supply more regular. The rivalries between the companies usually lowered the cost of energy to consumers, encouraging them to use more fossil fuels. In other words, despite being financial competitors, rival shippers worked together—sometimes intentionally, sometimes not—to increase energy demand. The synergistic effects of transport networks deserve at least as much attention as their competitive dynamics.

Second, thinking about energy landscapes draws our attention to the geography of energy transport and consumption. Canals, pipelines, and wires made new forms of energy available to people, but only in specific places. In the United States, residents of the mid-Atlantic reaped a disproportionate share of the benefits of fossil fuel energy in comparison with regions such as the South and West. However, there were intra-regional differences as well. Large eastern seaboard cities such as Philadelphia and New York gained the most from new energy supplies while the rural regions through which canals, pipelines, and wires shipped these goods benefited much less. Studying energy landscapes suggests that we pay attention to the geographic distributions of energy's costs and benefits.

Third, analyzing energy landscapes encourages us to study technological systems in action. Examining energy flows, although rarely as exciting as studying striking miners, wildcatting drillers, or plundering oil magnates, focuses our attention on

technologies in use.¹¹ Historians of technology have spent considerable effort over the last twenty years studying the invention and innovation stages of technological development but far less examining the social effects of technologies over their entire lifecycle.¹² There has been an implicit assumption that the early stages are the most important and that the social consequences of technological systems emerge from the decisions of inventors and early adopters. This is not necessarily the case. Looking at the operations of canals, pipelines, and wires over time allows us to compare their effects over several decades and analyze new patterns.

Organic Versus Mineral Economy

Canals, pipelines, and wires revolutionized the social energy practices of the mid-Atlantic between 1820 and 1930. They created energy landscapes capable of delivering ever-increasing amounts of fossil fuels, thereby facilitating the growth of an urban and industrial society. In particular, energy transport infrastructure played a crucial role in initiating the shift from an organic to a mineral economy in the mid-Atlantic.

¹¹ William Cronon noted that commodity flows tend to create mystification and boredom in people, but that there are benefits to their study: "I write of commodity markets not from some perverse private fascination, but from the conviction that few economic institutions more powerfully affect human communities and natural ecosystems in the modern capital world. Even those of us who will never trade wheat or pork bellies on the Chicago futures markets depend on those markets for our very survival. Just as important, the commodities that feed, clothe, and shelter us are among our most basic connections to the natural world. If we wish to understand the ecological consequences of our lives—if we wish to take political and moral responsibility for those consequences—we must reconstruct the linkages between the commodities of our economy and the resources of our ecosystem." Cronon, *Nature's Metropolis: Chicago and the Great West*, xvii.

¹² For critiques of historians of technology focusing too heavily on invention and innovation and too little on use, see: Langdon Winner, "Upon Opening the Black Box and Finding It Empty: Social Constructivism and the Philosophy of Technology," *Science, Technology, and Human Values* 18, no. 3 (1993); David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (Oxford: Oxford University Press, 2007).

The framework of organic and mineral economies is a remarkably useful way of understanding how and why fossil fuel consumption has changed our world.¹³ Yet despite the compelling nature of these concepts, they have failed to gain wider traction beyond a small group of energy and environmental historians.¹⁴ This is unfortunate. Given the high political, economic, and environmental stakes associated with our current energy practices, we need good frameworks for analyzing and addressing these issues.

In the remainder of this section, I detail the concept of organic and mineral economies, drawing heavily on the demographer E. A. Wrigley and the environmental historian Rolf-Peter Sieferle. I use this framework for three reasons. First, the transformation from an organic to a mineral economy is a very effective way of understanding the energy transitions that occurred in the mid-Atlantic between 1820 and 1930. Second, I seek to enrich our understanding of this framework by applying it to the American context and highlighting the importance of energy transport infrastructure for the creation of mineral economies. Third, I hope my use of these concepts encourages scholars, politicians, policy advocates, and citizens to consider the use of this framework in conceptualizing our energy challenges and developing solutions.

¹³ The most thorough treatment of this topic is by E. A. Wrigley: E. A. Wrigley, *Continuity, Chance and Change: The Character of the Industrial Revolution in England* (Cambridge: Cambridge University Press, 1988). The notion of a solar-agrarian regime developed by Rolf-Peter Sieferle expresses similar ideas in different language: Rolf Peter Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge: White Horse Press, 2001). Other scholars using this concept include: Andrews, *Killing for Coal: America's Deadliest Labor War*; Richard Wilkinson, "The English Industrial Revolution," in *Ends of the Earth*, ed. Donald Worster (Cambridge: Cambridge University Press, 1988); John Landers, *The Field and the Forge: Population, Production, and Power in the Pre-Industrial West* (Oxford; New York: Oxford University Press, 2003); Paul Warde, "Fear of Wood Shortage and the Reality of the Woodland in Europe, C.1450–1850," *History Workshop Journal* 62, no. 1 (2006); Vaclav Smil, *Energy in World History* (Boulder: Westview Press, 1994).

¹⁴ Sieferle's book, one of the clearest and most effective descriptions of the development of our energy practices, for example, is out of print in English and extremely difficult to obtain. Paul Warde's work is similarly limited in its distribution. One point of hope is that Thomas Andrews' recent Bancroft-prize winning book includes the shift from the organic to the mineral economy as a central thematic. Andrews, *Killing for Coal: America's Deadliest Labor War*.

Let me begin by sketching out the main characteristics of an organic economy through the ideas of one of its most famous analysts. Thomas Malthus was an English economist who lived and wrote in the decades surrounding the turn of the nineteenth century. He is most famous for his “principle of population,” which states that if population increases geometrically while food production increases at an arithmetic rate, as was happening in Europe at the time, it will lead to decreased standards of living, famine, and/or war. Malthus came to this pessimistic conclusion because he understood the deep connections between humans and the land. Simply put, land was the source of all goods and wealth. If you had a situation where you increased the number of humans without increasing the amount of land they inhabited, then per capita wealth would inevitably decline: “I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.”¹⁵ If population expanded enough, it would overtake the carrying capacity of the land.

Why did land matter so much? Malthus noted that human survival depended on at least four things: food, clothing, lodging, and fire. In an organic economy, all of these goods come from the land, either through growing crops (arable land), raising animals (pasture land), or firewood (forest land). Food comes from arable land (crops), pasture land (meat), and forest land (hunting and gathering). So does clothing (arable land for growing plants, pasture land for wool and leather, or forest land for hides). Lodging requires forest land either in the form of lumber for a house or firewood to operate kilns that produce bricks (even houses built of stone usually used significant amounts of wood

¹⁵ Thomas Robert Malthus, *An Essay on the Principle of Population, as It Affects the Future Improvement of Society. With Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers* (London: J. Johnson, 1798), 13.

for support). Fire for heating homes or cooking food requires land to grow combustible plant material. In addition, most manufacturing enterprises require raw materials from the land. Iron tools require iron ore and timber for charcoal. Tanners and leather-goods manufactures require pasture land for cattle. Brewing, distilling, salt-making, and pottery all require forest land for heating resources.

In a sparsely populated society, these constraints matter very little. However, in a densely populated world, like Europe at the end of the eighteenth century, these constraints were very real. Once the available land had been settled, increasing the output of one good meant having less of another.¹⁶ For example, increasing the supply of meat and wool required more pasture land, and therefore less arable or forest land for other purposes. From Malthus' perspective, it was only a matter of time before the dietary needs of an increasing population would require the reallocation of land towards food production, leaving less available for other purposes such as manufacturing. In other words, the pie of goods would at best grow incrementally while the number of people requesting slices would grow much more quickly. The result would be fewer and less satisfying slices of pie. Because of its dependence on the carrying capacity of the land, the organic economy operated as a zero-sum game.

Malthus was not the only one who saw the world this way. Adam Smith and David Ricardo shared his pessimistic views on the limits to growth.¹⁷ In assessing the three factors of production—land, labor, and capital—they saw that the supply of land

¹⁶ There were some opportunities for improving land yields without fossil fuel energy. Wrigley notes that England developed an “advanced organic economy” between 1600 and 1800 by increasing the use of animals. Work animals increased the amount of labor at the disposal of workers (making it practical to transport and use marl, for example) and produced manure that increased yields. Wrigley, *Continuity, Chance and Change: The Character of the Industrial Revolution in England*, chapter 2.

¹⁷ E. A. Wrigley, “The Limits to Growth: Malthus and the Classical Economists,” *Population and Development Review* 14, Supplement: Population and Resources in Western Intellectual Traditions (1988).

could not be expanded. It was therefore subject to the law of diminishing returns: coaxing more output from the land would require increasing the labor and/or capital inputs. Each improvement to the land meant that the next improvement would require a greater amount of labor or capital to achieve. Applied to the economy as a whole, this implied that while economic gain might be made in the short term—witness Smith’s parable of the pin-makers—the law of diminishing returns promised an eventual return to a stationary state.¹⁸ Every improvement made the next one harder.¹⁹ In modern terms, we would describe the constraints of the land as a negative feedback loop.²⁰

The structural relationships between land and society in an organic economy had important implications for energy practices. First, all energy was derived from the flow of solar energy through the ecosystem. Plants used photosynthesis to transform solar energy into food or combustible material, and the thermal energy of the sun created wind and rain patterns that could move boats and turn mill wheels on streams. Second, humans got most of their energy from the land, as plant material to eat, to feed animals, or to burn.²¹ As a result, the carrying capacity of the land presented finite limits to

¹⁸ Adam Smith described gains in pin-making through the specialization of labor and the more efficient use of energy. By dividing the tasks, workers could greatly increase the total output of pins. The key for Malthus was the division of labor, *not* the application of machinery or the greater use of energy. Moreover, once the new processes were implemented, any future gains would be harder to achieve. Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, 3 vols. (Dublin: Whitestone, 1776).

¹⁹ Mark Elvin describes a similar process in China during the eighteenth century where continual advancements over the previous centuries made incremental growth increasingly difficult. He terms this a “high-level equilibrium trap”: Mark Elvin, *The Pattern of the Chinese Past* (London: Eyre Methuen, 1973), Chapter 17.

²⁰ This perspective helps explain why mercantilism was the predominant economic theory of the day. By colonizing new territories, nations could increase the land available to them, thereby removing some of the limits to growth. While the law of diminishing marginal returns might eventually catch up with them, the great increases in raw materials that became available with the colonization of new lands opened the possibility for extended economic gains for a period of time.

²¹ In 1600, for example, Paul Warde estimates that wind and water power represented at most 1.5% of the total energy supply used by humans in England and Wales. Over 75% of the energy came from human muscles, animals, and firewood. Much of the remaining energy came from the isolated burning of coal in

energy supply. Once all the available land was being used at or near its capacity, there was no way to increase energy significantly. Third, energy use was local. There were significant barriers to transporting energy over long distances.²² The cost of firewood doubled every 2-4 kilometers it was shipped over land, while the energy from a water wheel could only be used within a very short distance from the river bank.²³

These features of energy supply in an organic economy influenced how and where people lived and worked. First, because energy was local, energy-intensive enterprises needed to be established near abundant forests, falling streams, or rural areas with few competing demands for energy supply. Cities, by contrast, were energy-poor due to the limited ability to import energy, multiple demands for energy supplies, and small amounts of land. Agricultural communities tended to form at sites where there was enough water power available for mills. Commercial societies congregated where river currents and ocean breezes made transport easier. Finally, because of the local nature of energy availability, most communities had to be largely self-sufficient in terms of energy. It made little sense to talk of national trends when the cost of transporting firewood doubled every few miles and the power of streams was limited to particular places. Communities lived on their own islands of energy supply.²⁴

In an organic economy, societies faced finite limits to growth based on the carrying capacity of the land and the ability of humans to tap into the flow of solar energy. Whether expressed through the concept of diminishing returns, the stationary

brewing and salt manufacturing. Paul Warde, *Energy Consumption in England and Wales, 1560-2000* (Consiglio Nazionale delle Ricerche (CNR), Istituto di Studi sulle Società del Mediterraneo (ISSM), 2007), 60, 69.

²² As discussed later in this section, this feature of energy in an organic economy was a big part of the reason transport infrastructure was crucial to the development of a mineral economy.

²³ Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 59.

²⁴ Ibid.

state, or negative feedback loops, the organic economy was not a world in which constant growth could or was expected to occur. Growth was not impossible, but it was the exception rather than the norm, and the law of diminishing returns promised a return to the stationary state. For example, the Netherlands achieved phenomenal commercial success in the seventeenth century by controlling much of Europe's international trade and drawing on the land resources of other parts of the world. However, once the Dutch could no longer increase their land holdings, their trade empire entered a period of decline.²⁵ Limits were an inevitable part of the organic economy, lending credibility to the Malthusian worldview.

As it turned out, the classical economists were wrong. Not long after Malthus's publication of his ideas, England, followed by other nations, entered a long period of sustained economic growth that exceeded anything seen before. The process of industrialization broke through previous limits to growth and generated long-term increases in output, wages, and standards-of-living. The negative feedback loops of the stationary state were replaced by positive feedbacks. With fossil fuel energy, each improvement made the next one easier.

The classical economists were wrong because they were describing an organic economy. The application of mineral energy sources—first coal, and later oil and electricity—would shatter the linkages between the land and economic growth that

²⁵ The decline of Holland's trading empire was a multi-factored process, but the country's lack of ability to sustain a mineral revolution played a major role. Holland continued its economic growth in the 18th century by burning its native peat stocks, but once these were largely depleted, it lost its leading economic status: William H. TeBrake, *Medieval Frontier: Culture and Ecology in Rijnland* (College Station: Texas A&M University Press, 1985).

Malthus, Smith, and Ricardo had identified. In other words, they failed to appreciate the revolutionary possibilities of fossil fuel energy.²⁶

When a society begins to use fossil fuels intensively, it alters the three relationships between energy and society that characterize the organic economy. First, fossil fuels eliminate limits to growth by separating the links between energy and the carrying capacity of the land. Second, people in mineral economies tap *stocks* of energy built over millions of years rather than the immediate flow of solar energy.²⁷ Third, fossil fuels create the possibility for the intensive long-distance transport of energy thereby separating sites of energy production and consumption. These shifts replace the zero-sum trade offs of an organic economy with the possibility of continual growth.

In an organic economy, land is needed for the four necessities of life: clothing, housing, food, and fire. In a mineral economy, fossil fuels directly replace land through substitution (as when coal replaces firewood in homes and heat-intensive industries or when coke replaces charcoal in iron production) or by dramatically increasing the value of existing land (such as raising farm yields with fossil fuel-based fertilizers). By freeing the land for other purposes, fossil fuels allow the exponential increase of the production of goods: the pie can get bigger and bigger. For example, if in 1820 British iron production had used charcoal, that industry alone would have required a forest the size of the entire land area of the British Isles.²⁸ But by substituting coal for charcoal, Britain could lead the world in iron production and feed a population of several million people—

²⁶ This is not a critique of the classical economists. Their assessment of the economic possibilities of their time was based on the best knowledge of their day. The revolutionary impacts of mineral fuels would not be apparent for several decades.

²⁷ While hydrocarbons are also the products of solar energy (plants and animals which decomposed in an oxygen-poor environment) they represent energy surpluses from millions of years of sunshine.

²⁸ Siefert, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 103.

an impossible situation in an organic economy. With fossil fuels, the pie could get larger and larger.

Because fossil fuels are the stored energy of millions of years of sunlight, they dramatically increase the energy available to society in a given moment. Mid-Atlantic residents increased the production of anthracite coal from a few hundred tons in 1820 to more than ten million tons in 1860 and nearly sixty million tons by 1900.²⁹ Oil production increased from several thousand barrels in 1860 to forty-eight million barrels in 1900 and nearly a billion barrels by 1930.³⁰ This amount of fossil fuel energy far exceeded the potential of land-based organic sources. For example, Pennsylvania's production of coal in 1900 provided the energy equivalent of a forest four times the size of the state.³¹

Moreover, the energy density of fossil fuels makes the development of transport infrastructure economically viable. Organic energy sources tend to be decentralized and lack the density necessary to justify extensive alterations of the built environment for their transport.³² This is why farmers in areas without transport infrastructure deliver

²⁹ Miners' Journal, *Coal Statistical Register for 1870* (Pottsville, PA: Miners' Journal Office, 1870); United States Geological Survey, *Mineral Resources of the United States, 1901* (Washington: Government Printing Office, 1902), 295.

³⁰ Sam H. Schurr and Bruce Carlton Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects* (Baltimore: Johns Hopkins Press, 1960), 93.

³¹ Pennsylvania produced 57,367,915 tons of anthracite and 79,842,326 tons of bituminous coal in 1900 (average BTU value 25,400,000 per ton). These provided the thermal equivalent of 169,317,564 cords of wood (average BTU of 20,960,000 per cord). As the sustainable yield of one cord of wood requires 2/3 of an acre, this would necessitate 112,878,376 acres, or 176,372 square miles (there are 640 acres in a square mile). As Pennsylvania's area is 46,055 square miles, coal provided the heat equivalent of a forest nearly four times the state's total area. BTU values from Ibid. Forest yields from Michael Williams, *Americans and Their Forests: A Historical Geography* (Cambridge: Cambridge University Press, 1989), 106.

³² Sieferle notes that there are finite limits to how far grain can be transported: "a human can carry a maximum of 40 kg of grain over a distance of 25 km in one day and he consumes in this time period about a kilogram of grain. If the return trip and a day sojourn at the point of origin and the goal are counted in, he will use 16% of the carried load for a distance of 50 km, 25% for 100 km. If he were supposed to travel a

their corn to markets in the form of whiskey and pigs—commodities that have a much higher weight-value ratio than corn. Firewood is spread out over large forests in a relatively thin layer that would be less than four inches thick if distributed evenly. By contrast, coal seams are often found in deposits several feet thick with as many as 30 to 120 layers on top of one another. This means that the energy yield from a single place is at least 300 times (and often several thousand times) greater than coal with firewood.³³ As a result, there is much greater incentive for capital investment in transport infrastructure with fossil fuels because the costs can be recouped through the high volume of traffic. This is one of the central reasons canals, pipelines, and wires were so important to the creation of the mineral economy.

Once a society develops a mineral economy, it creates new possibilities for the geographic distribution of people, industries, and goods. Rather than having to be located along the paths of falling streams, energy-intensive industries can be established anywhere mineral fuels can be easily transported. Most of the time, this has meant the move of industry from rural to urban areas. More people can live in cities because there is abundant energy for homes and factories. Mineral fuels also allow changes in transport networks by encouraging the construction of railroads and steamboats that can travel across land and upriver.

There are limits in a mineral economy, but they are on a completely different order of magnitude from an organic economy. In the long term, fossil fuels are an exhaustible resource. Coal taken out of a mine or oil pumped from the ground cannot be

distance of 500 km, he would not be able to feed himself with the grain carried along.” Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 22.

³³ Ibid., 124-125.

replaced, except through millions of years of geological action. Eventually, we will need to return to a system whereby our energy supply is derived from flows, not stocks. However, in the short term, and for our hydrocarbon age that is measuring in centuries, supplies of energy are practically infinite. The historical pattern is that their use can be expanded to suit human needs without zero-sum trade offs.

Mineral economies enable and amplify industrialization, but they are not synonymous with it. Due to the limits of growth characteristic of the organic economy, no amount of capital investment, technological acumen, or specialization of production could lead to the rapid, sustained growth first seen in Britain towards the end of the eighteenth century and later in the United States and many parts of western Europe. For example, by the eighteenth century many regions in China had developed sophisticated manufacturing practices that produced high quality goods. Without fossil fuel energy, however, these industries never experienced the sustained and self-reinforcing growth of mineral-powered industrialization in Europe and the United States.³⁴ Conversely, the presence of mineral energy sources is not a guarantee of industrialization: several regions in the United States and around the world have been endowed with fossil fuels and yet have not developed an industrial society.³⁵

Thinking in terms of organic and mineral economies is useful because it draws our attention to the deep interconnections between energy and society. Contemporary political debates about energy err by devoting too much attention to short-term and

³⁴ Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, N.J.: Princeton University Press, 2000).

³⁵ For example, the extensive coal deposits on the James River near Richmond did not lead to an industrial society in Virginia. Sean P. Adams, *Old Dominion, Industrial Commonwealth: Coal, Politics, and Economy in Antebellum America* (Baltimore: Johns Hopkins University Press, 2004).

nationalistic issues like energy independence and eliminating oil payments to hostile governments. We would be better served by discussing the fundamental links between energy, environment, and the provision of human necessities. Running out of fossil fuels will not simply alter how we get energy; it will transform how we allocate land, what types of goods our society is able to produce, and how many people our planet can support. We would be wise to remember the cautionary tale of Malthus—the constraints of the organic economy may be in our future.

Regional Analysis

Energy Landscapes analyzes the development of the mineral economy in the American mid-Atlantic. As such, it is a regional analysis.³⁶ I have used this approach for several reasons. First, it reflects the fact that there were important regional variations in energy practices throughout America between 1820 and 1930.³⁷ The South used very little fossil fuel energy, relying mainly on large tracts of forest for heating, cooking, and manufacturing. New England was endowed with fast-moving streams and led the nation in the use of water power. Settlers in the Northwest Territory took advantage of the large forests to derive most of their fuel from trees felled to clear the land. The settling of the

³⁶ There are several methods of doing regional analysis. One approach is to study a particular area through the perspective of culture, ethnicity, and settlement patterns. A seminal work using this approach is James T. Lemon, *The Best Poor Man's Country: Early Southeastern Pennsylvania* (Baltimore: Johns Hopkins University Press, 2002 [1972]). Another approach, favored by environmental historians, is to highlight a central feature of a region. I am following the latter approach. This project uses regional analysis to highlight particular energy patterns similar to the ways that Hudson analyzed corn in the Midwest, Cronon studied grain, meat, and lumber in Chicago and the Great West, and White followed the uses of the Columbia River. White, *The Organic Machine*; Hudson, *Making the Corn Belt: A Geographical History of Middle-Western Agriculture*; Cronon, *Nature's Metropolis: Chicago and the Great West*.

³⁷ Over the last eighty years, many of these differences have narrowed, largely because the spread of fossil fuel transport infrastructure across the continent has made coal, oil, and electricity cheap and abundant in most regions of the United States.

Great Plains was at first limited by the shortage of energy resources. A regional approach allows us to see wide differences between the energy practices of different areas.³⁸

Second, and most importantly, the energy practices of the mid-Atlantic, more than any other American region, have shaped our contemporary world. It was in the mid-Atlantic that Americans first began to use fossil fuels intensively and pioneered the transition into a mineral economy. Other regions, in America and across the globe, took notice. The economic success that resulted from the mid-Atlantic's consumption of fossil fuels encouraged other regions to emulate its development patterns. The roots of American fossil fuel dependency, therefore, can be found in the energy history of the mid-Atlantic.

The energy landscapes I examine were largely, but not exclusively, contained in the mid-Atlantic region. Conventionally, the mid-Atlantic is considered the states of Pennsylvania, New Jersey, and New York, while Delaware and Maryland are sometimes included. The principal cities of the region are New York, Philadelphia, and Baltimore, although other cities including Pittsburgh, Buffalo, Harrisburg, Albany, Trenton, and Wilmington also figure in this story. However, canals, pipelines, and wires did not always respect political boundaries or conventional definitions of the mid-Atlantic. For example, the anthracite canal network operated primarily in the eastern half of the mid-Atlantic while the oil pipeline network extended west to Cleveland and Chicago. The

³⁸ This view is more useful than relying on national averages. For example, it is a widely cited fact that the United States derived more of its energy from wood than any other source until 1885. While this may be true for the nation as a whole, it is more useful to observe that many regions (like the South) obtained virtually all of their energy from wood while others (like the mid-Atlantic) had already become dependent on hydrocarbons for the majority of their energy needs.

Holtwood Dam in Pennsylvania sent most of its electricity to Baltimore while the Conowingo Dam in Maryland supplied Philadelphia.

When there is a tension between the conventional boundaries of the mid-Atlantic region and the paths of canals, pipelines, or wires, I follow the latter. My central arguments are about energy, not the specific boundaries of regions. Moreover, I do not treat all parts of the mid-Atlantic equally. I focus most of my attention on those sites where energy was produced, transported, and consumed—those parts of the mid-Atlantic that were part of the energy landscapes I analyze. Therefore, rather than trying to give an exhaustive account of the region, this dissertation is a study of energy landscapes that are predominantly contained in the mid-Atlantic.

Disciplinary Approaches

My approach throughout *Energy Landscapes* integrates history of technology, environmental history, and business/economic history. Intellectually, my primary models are William Cronon's examination of commodity flows shaping regional development and environmental change, E. A. Wrigley's study of the relationships between energy and industrialization, and Thomas Hughes' analysis of large technical systems.³⁹

In addition to drawing on works in history of technology, business/economic history, and environmental history, I hope my work will contribute to the intellectual development of these fields. For historians of technology, I focus on the properties of

³⁹ Cronon, *Nature's Metropolis: Chicago and the Great West*; Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*; Wrigley, *Continuity, Chance and Change: The Character of the Industrial Revolution in England*.

infrastructure and the study of technologies in use.⁴⁰ One of the benefits of this approach is that it offers a way past long-standing debates over technological determinism. For a variety of disciplinary and intellectual reasons, historians of technology have spent much of the last two decades debunking stories of technological determinism.⁴¹ While these attacks have largely been correct, they have had the unintended consequence of encouraging narrow scholarship focused disproportionately on the invention and innovation of technologies. This is unfortunate because it has meant that many important stories have not been told. In *Energy Landscapes*, I seek to balance these approaches. Canals, pipelines, and wires were not determinative technologies; they could have been built differently or not at all, different parties could have managed them, and societies could have made different energy choices. However, once these technologies were built and operated in the particular social and economic context of the mid-Atlantic, they shaped the energy practices of the region in powerful ways. Looking at the ways technologies in use shape social choices strikes me as an effective way around debates over social construction versus technological determinism.

For business and economic historians, I seek to connect the financial operations of canals, pipelines, and wires to their broader social effects. Despite widespread agreement that businesses have been critical to American history, many historians ignore the academic subfields of business and economic history. While there are many reasons for this oversight, part of the explanation is that works in these fields sometimes fail to connect with questions that are central to other historians. In *Energy Landscapes*, I seek

⁴⁰ See my discussion of these issues earlier in the introduction under the heading “Transport Infrastructure & Energy Landscapes.”

⁴¹ Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History?: The Dilemma of Technological Determinism* (Cambridge, Mass.: MIT Press, 1994).

to provide an example of work that integrates the business and economic aspects of transport infrastructure with broader issues of historical interest, such as environmental change, urbanization, industrialization, and the nation's political economy.⁴²

Finally, I hope to contribute to scholarship in environmental history that deepens our understandings of the structural relationships between humans and the environment. At first glance, this is not the theme that one might expect for an environmental history of energy. This work is not about the connections between fossil fuels and global warming. Nor is it centrally concerned with the environmental damage caused by producing, transporting, and consuming energy sources, although these issues are discussed in the text. Instead, I use the concepts of energy landscapes and organic and mineral economies to demonstrate how patterns of human life that are often taken for granted depend on contingent relationships between human societies and the natural world. Cheap and abundant fossil fuel energy, large urban populations, and industrial economies are not natural or inevitable features of the world that we live in. They exist only because (a) human societies have created a built environment that permits ever-increasing flows of energy from place to place and (b) the natural world has supplied an abundance of fossil fuels. It would be foolish for humans to expect these same conditions to hold forever.

A Story at Three Levels

A major topic of debate in contemporary history is whether we should study the past through micro-studies that give a close focus on a small part of the world and a

⁴² Many of these themes were discussed at a recent conference on the future of business history at the Hagley Museum & Library. I presented a paper at the conference that discusses the ways my work seeks to bridge the divide between business historians and American historians more generally. Christopher Jones, "More Than Which Capitalist Wins" (paper presented at "Business History as Critique: Questions, Concepts, Boundaries, and Audience" conference, Hagley Museum & Library, Wilmington, DE, May 15, 2009).

restricted chronology or through macro-studies that take a much broader and less detailed view of change over time. This is a complex debate involving questions of historical methodology, shifts in the economics of book publishing, and tensions between academic and public history. The strengths of big-picture analyses are that they can make sense of broad sweeps of history, provide new frameworks for interpretation, and engage broader audiences. The drawback of this approach is that the scholarship is often based on secondary literature which leads to questions about whether the work is saying something new or simply summarizing what is already out there. By contrast, micro-histories are the most common form of historical research. Some strengths of this approach are that authors are able to access new primary sources, provide a detailed and specific account of change, and demonstrate the historical contingencies of a particular development. The main drawbacks of this approach are that micro-histories often fail to inform scholarship outside their narrow purview and lack widespread appeal.

My dissertation seeks to navigate between Scylla and Charybdis by integrating micro- and macro-level histories with a middle-level analysis. Several scholars have noted that middle-level analysis can strengthen “little picture” histories by exploring how particular case studies relate to the whole. In addition, middle-level analysis can provide an additional degree of detail and grounding to conclusions drawn at the macro level. Thomas Misa has made this argument in the context of history of technology, while Paul Edwards has noted that infrastructure is a particularly suitable topic for middle-level analysis.⁴³

⁴³ Thomas J. Misa, "Retrieving Sociotechnical Change from Technological Determinism," in *Does Technology Drive History?: The Dilemma of Technological Determinism*, ed. Leo Marx and Merritt Roe

These ideas are embodied in the structure of my dissertation, which is a story told at three levels of analysis: micro-, middle-, and macro-. The micro-level analysis of my dissertation is represented by case studies of the Lehigh Canal, the Tide-Water pipeline, and the transmission wires extending from the Holtwood Dam (chapters 1, 3, and 5). The middle-level sections study the patterns of flow and consumption of coal, oil, and electricity along the networks of transport infrastructure (chapters 2, 4, and 6). The slow and non-linear shift from an organic to a mineral economy that occurred in the mid-Atlantic is the macro-level analysis (introduction, chapters 2, 4, 6, conclusion). By using each level of analysis to inform the others, my study offers a broad perspective, grounded in the historical details, on the importance of energy transport infrastructure in the mid-Atlantic between 1820 and 1930

Dissertation Contents

Energy Landscapes consists of three sections analyzing the transport and consumption of coal (1820-1860), oil (1860-1900), and electricity (1900-1930). Each section has two chapters. The first shows how the construction of canals (chapter 1), pipelines (chapter 3), and transmission wires (chapter 5) transformed the built environment of the mid-Atlantic, thereby creating new energy landscapes in which coal, oil, and electricity could be consumed in ever-increasing amounts. The second chapter in each section traces the flow of coal (chapter 2), oil (chapter 4), and electricity (chapter 6) along these networks and analyzes the social impacts of new fossil fuel consumption patterns.

In the first chapter of each section, I examine the construction of a pioneering energy transport technology and how it stimulated the creation of a broader network of canals, pipelines, or wires in the region. The Lehigh Canal, Tide-Water pipeline, and transmission wires extending from the Holtwood hydroelectric dam on the Susquehanna River were path-breaking technologies that transformed the energy options available to mid-Atlantic residents.⁴⁴ In the first half of each of these chapters, I study the social choices, power struggles, and historical contingencies that shaped their development, exploring who paid for them, how and where they were built, and how they influenced the broader coal, oil, and electrical industries. In the second half of these chapters, I analyze the rise of a network of several canals, pipelines, or wires that emerged in response to these pioneering case studies. I show how these region-wide infrastructure networks created new energy landscapes that altered the built environment of the mid-Atlantic, thereby triggering the growth of fossil fuel consumption. The sources for these chapters are corporate records, trade journals, newspaper articles, government reports, and secondary literature.^{45, 46, 47, 48}

⁴⁴ Although hydroelectricity is not a fossil-fuel based source of energy, most electricity in the mid-Atlantic during this period came from burning coal. I chose this case study because it most effectively illustrates the energy transport and consumption transitions that took place during this period.

⁴⁵ In this work, I have drawn on any sources that have helped me answer the questions that I have posed. As it has turned out, archival sources have proved less beneficial to this work than is typical in a historical dissertation. This is partly because of the limits of the materials (there are almost no archival records I could find for the Tide-Water pipeline and despite the fact that there are many records for the Holtwood Dam, most of them concern financial operations, not the construction of transmission wires) and partially because of the questions I am interested in. During my research, I have found that trade journals, government reports, and secondary literature have been the most useful sources for my project.

⁴⁶ The corporate records of the Lehigh Coal and Navigation Company are available in several locations, with the most complete set at the Pennsylvania State Archives in Harrisburg, PA. Relevant trade journals for understanding the coal trade include *The Miners' Journal* (Pottsville, PA), *Hazard's Register* (Philadelphia, PA), and *Niles Weekly Register* (Baltimore, MD). Government documents reviewing the coal trade include the decennial Census of Manufactures as well as "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade," (Harrisburg: Henry Welsh, 1834); United States. Dept. of the Treasury. and Louis McLane, *Documents Relative to the Manufacturers in the United States*, 2

In the second chapter of each section, I analyze the social impacts of the new landscapes by studying the energy consumption patterns along the canal, pipeline, or wire network. First, I explore how these technologies shaped the geographic distribution of coal, oil, and electricity by detailing where these resources were consumed. I compare consumption at the site of production, along the path of the canal, pipeline, or wire, and at its terminus. Second, I study how coal, oil, and electricity resources were consumed and how these energy practices contributed to the development of a mineral economy. Third, I conclude by analyzing the intra-regional differences in energy consumption that led to an uneven distribution of costs and benefits, the steps that led society to become dependent on fossil fuel energy, and the ways that coal, oil, and electricity shaped broad

vols. (Washington: Printed by D. Green, 1833); Secretary of the Treasury, *Report on Steam Engines* (Washington, DC: Thomas Allen, Printer, 1838). Secondary literature on the Lehigh Canal includes Anthony Brzyski, "The Lehigh Canal and Its Economic Impact on the Region through Which It Passed, 1818-1873" (Ph.D. Dissertation, New York University, 1957); Joan Gilbert, *Gateway to the Coalfields: The Upper Grand Section of the Lehigh Canal* (Easton, PA: Canal History and Technology Press, 2005); Michael Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania* (Easton, PA: Canal History and Technology Press, 2001).

⁴⁷ There is no central repository of records for the history of the Tide-Water pipeline, although I have found relevant materials at the Drake Well Museum in Titusville, PA, the Hagley Museum and Library in Wilmington, DE, the Rockefeller Archives in Tarrytown, NY, and the Yale Manuscripts and Archives Library in New Haven, CT. Relevant trade journals include *The Titusville Morning Herald* (Titusville, PA), *The Oil City Derrick* (Oil City, PA), and *Oil, Paint, and Drug Reporter* (New York, NY).

Government documents reviewing the oil trade include New York Assembly, *Proceedings of the Special Committee on Railroads, Appointed to Investigate Alleged Abuses in the Management of Railroads Chartered in the State of New York*, 8 vols. (Albany: 1880); House of Representatives, "Report on Investigation of Trusts," (Washington, DC: Government Printing Office, 1888); Industrial Commission, "Preliminary Report on Trusts and Industrial Combinations," (Washington, DC: 1900). Secondary literature includes Allan Nevins, *Study in Power* (New York: Scribner, 1953); Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*; Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906".

⁴⁸ The corporate records for the Holtwood hydroelectric dam are located at the Hagley Museum and Library in Wilmington, DE as part of the Pennsylvania Power & Light Company collection. Relevant trade journals include *Electrical World* (New York, NY) and *Transactions of the American Institute of Electrical Engineers* (New York, NY). There is no secondary literature treating the Holtwood dam or its transmission wires in significant depth. Useful secondary sources on transmission wires in the mid-Atlantic include David E. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940* (Cambridge, MA: MIT Press, 1990); Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*; Bayla Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970" (Dissertation, University of Pennsylvania, 1983).

regional transformations in how people lived, worked, and played. The sources for these chapters are statistical compendiums of energy flows listed in trade journals, corporate records, government reports, consumer surveys, and historical analyses of energy industries.⁴⁹

In 1820, fossil fuel energy played only a minor role in the society and economy of the mid-Atlantic. Residents of the region lived in an organic economy, only using small amounts of coal in seaboard cities and small towns located on or near coalfields. A few people had noted the presence of anthracite coal in northeast Pennsylvania, within a hundred miles of Philadelphia and New York City. Some had even formed companies hoping to profit from its sale in urban markets, but had been thwarted by the lack of transport infrastructure and minimal demand for coal. A casual observer would have had little reason to anticipate a dramatic change in this state of affairs. And yet, by the dawn of the Civil War, organic energy sources were already being superseded by fossil fuels. How, when, where, and why did this happen? It is with these questions that our story begins.

⁴⁹ These chapters draw on many of the same sources identified in the previous paragraph. For example, both trade journals and government reports included information on the construction of canals, pipelines, and wires as well as the transportation and consumption of energy. For coal, *The Miners' Journal* includes weekly reports and yearly summaries of coal shipments, and *The Titusville Morning Herald* offers comparable analysis for oil. Statistics on electricity consumption are available from United States Bureau of the Census., *Census of Electrical Industries: Central Light and Power Stations, 1902-1927* (Washington: Government Printing Office, 1905-1930). Secondary literature studying energy consumption includes Frederick Moore Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860* (Harrisburg: Commonwealth of Pennsylvania, Pennsylvania Historical and Museum Commission, 1974); David E. Nye, *Consuming Power: A Social History of American Energies* (Cambridge, Mass.: MIT Press, 1998); Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*.

Chapter 1: The Lehigh Canal and the Energy Landscape of Anthracite Coal, 1820-1860

When a group of men piloting crude wooden rafts piled with black stones arrived at the Philadelphia port in 1820, a casual observer would have had little reason to take notice. There was nothing remarkable about rafting goods down the Delaware River to the region's main trading center. After all, farmers, traders, and lumbermen had been delivering wood, agricultural products, and other goods from the areas north of Philadelphia for decades along this route. The boatmen and arks appeared to be simple extensions of well-established trade patterns.

Upon closer inspection, however, two things were different about these boatmen. The first is where they came from. Their journey began on the recently improved Lehigh River. Several hundred workers had spent the better part of the previous two years in the river, creating dams, stone walls, and hydro-static gates that would allow the regular shipment of goods down the river. Through their efforts, the natural flows of the Lehigh River were funneled, trapped, and regulated to suit the needs of human commerce. It was the most significant transformation of a waterway in the mid-Atlantic at the time.

The second distinctive thing about these men was their cargo: anthracite coal from the Lehigh Valley. At the time, our hypothetical observer would have been unlikely to ascribe much importance to these deliveries. Although Philadelphia craftsmen were accustomed to using bituminous coal imported from Britain, Nova Scotia, and Virginia, there was no active trade in the state's "stone coal" as anthracite was more commonly known. The city's coal market was small and well-stocked. There was no pent-up

demand for anthracite. It was easier for the men to break up the arks and sell them as lumber than to create a new market for anthracite coal.

With the advantage of historical hindsight, however, the true importance of these boatmen and their cargo becomes clear. Over the next forty years, anthracite coal would trigger revolutionary changes in the economy, environment, and society of the mid-Atlantic. Stone coal would be used to forge iron, build railroads, power steam engines, propel boats, and keep people warm. Anthracite would create great wealth for some, support dense concentrations of people, and enable the mid-Atlantic to develop an industrial economy. As residents of the mid-Atlantic became accustomed to using coal, their appetites for fossil fuel energy grew at a remarkable rate. While it was difficult to sell a few hundred tons of coal in 1820, by the dawn of the Civil War consumers required annual deliveries of several million tons to maintain their way of life.

How did this happen? The improvement of the Lehigh River was part of a broader transformation of the region's built environment that created new flows of goods and people. The flow of one product outweighed all others, both literally and figuratively: anthracite coal. By connecting the rich coalfields of the upper Lehigh Valley with Philadelphia, the Lehigh Canal gave the Quaker City a new energy hinterland. In conjunction with comparable developments along the Schuylkill, Delaware, and Hudson rivers over the next decade, coal canals gave rise to a new energy landscape in the mid-Atlantic. The most salient feature of this energy landscape was that coal could be delivered from rural areas to urban consumers cheaply, reliably, and in ever-increasing quantities.

The nexus of canals, boosters, and consumers provided the foundations for the development of a mineral economy in the mid-Atlantic between 1820 and 1860. Canals delivered anthracite coal in ever-increasing quantities and at steadily decreasing prices. Boosters encouraged consumer demand by creating new applications for anthracite, teaching users techniques how to burn it in homes and factories, and advertising its benefits. Thousands of consumers made individual decisions about where to live, how to heat their homes, and what type of power sources to use. Ultimately, these forces operated in a synergistic feedback cycle whereby canals increased supply, boosters found new applications for coal, and consumer demand encouraged the expansion of the energy landscape to further increase supply. The limits and negative feedback loops of the organic economy were soon replaced by the mineral economy's pattern of continual growth.

These changes began on the Lehigh River. In this chapter, I focus on the development of the Lehigh Canal to show the choices, struggles, and contingencies that shaped the construction of energy transport infrastructure in the mid-Atlantic. I begin by studying organic and mineral energy sources in the mid-Atlantic before the development of transport infrastructure. Next, I analyze the early development of the Lehigh Canal, focusing on how it transformed the built environment of the Lehigh River. Over the next decades, the increasing demand for coal required significant extensions to the canal system in order to supply the region's growing fossil fuel appetite. In the fourth section, I explore the broader network of canals that operated throughout the mid-Atlantic and highlight their points of similarity and difference with the Lehigh Canal. Finally, I review the patterns of increasing coal consumption, the creation of the anthracite iron

industry, and the transition to railroads as the primary transporters of coal at the dawn of the Civil War. The next chapter will study the patterns of anthracite flows and consumption to demonstrate how these practices created the first stages of a mineral economy in the mid-Atlantic.

Energy in the Mid-Atlantic, pre-1820

In 1820, the mid-Atlantic operated as an organic economy. Much like the rest of the United States, human muscles and firewood provided the large majority of the energy that people needed for farming, crafting goods, heating homes, and cooking food. Only small amounts of coal were used, mostly by craftsmen in cities like Philadelphia and New York or the northeastern parts of Pennsylvania where anthracite coal was plentiful. Industrial sites were largely concentrated along the falls of rivers or in rural areas where there were no competing demands for firewood. Most of the population was engaged in agriculture and relied almost wholly on organic energy sources in their daily lives.

Muscles, water, and wood were not limiting factors for mid-Atlantic residents at the time. As European observers had noted since arriving in the New World, the abundance of forests and land offered what seemed to be limitless possibilities. If anything, people believed there were too many trees as the dense forests made it difficult to clear the land or travel across it. There were several rivers with falls that could be used to power mills and the large amounts of unsettled land could feed plenty of draft animals. Given the low population density and small energy demands of the region's farmers, merchants, and craftsmen, energy shortages were not a chronic condition for most of the mid-Atlantic.

However, the existence of large amounts of organic energy did not dissuade certain residents of the mid-Atlantic from seeking to develop the region's coal resources. Three factors inspired boosters. First, various groups like blacksmiths, nail smiths, distillers, and the water works in Philadelphia were already using bituminous coal imported from Britain, Nova Scotia, and Virginia.¹ While the trade was small—for example, in 1784, Philadelphia imported around 500 tons of coal, just over 1,000 tons by the early 1790s, and about 3,000 tons per year by the 1810s—boosters saw the potential to replace foreign imports with domestic supplies.² Second, the presence of coal in northeastern Pennsylvania had been known for several years. As early as the 1770s, farmers and craftsmen in Wilkes-Barre and the Wyoming Valley used anthracite coal regularly. By the 1790s, large deposits had been identified in the Lehigh Valley and small amounts of anthracite from the Schuylkill region were being marketed in Philadelphia in the 1810s.³ There was coal near Philadelphia, but transporting it was cumbersome and expensive.

Third, and most important, boosters sought to replicate the industrial and economic success of Britain by building a trade in coal. For example, Thomas Cooper, a professor of chemistry at several American colleges, argued that coal was the source of

¹ Coal is commonly divided into three classes based on each deposit's percentage of carbon. Coal that is more than 90 percent carbon is labeled anthracite. Coal that is roughly 70-90 percent carbon is classed as bituminous. Coal with less carbon than bituminous is lignite. There are differences between these classes of coal that shaped their use, as will be discussed throughout the next two chapters. The most important differences are that anthracite is much harder to light because there are fewer volatile gases, but once lit, it burns with a cleaner flame.

² Philadelphia's population during these years was 28,522 in 1790, 41,220 in 1800, and 53,722 in 1810 according to the Census. Coal import numbers from Howard Benjamin Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite* (University Park: Pennsylvania State University Press, 1978), 9, 24-25.

³ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, chapter 1; Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 16.

British wealth: “In this country every suggestion that brings forward the importance of coal to the public view is of moment: we know little of its value in Pennsylvania as yet. All, all the superior wealth, power and energy of Great Britain, is founded on her coal mining.”⁴ Josiah White, pioneer of the Lehigh Canal, further made the case for the links between coal, canals, and financial success in an article in *The Democratic Press*: “It is a general belief that the extraordinary personal industry of the English people is the cause of the wealth of that empire. I ask, what would the value of all their labor be, in all their commercial articles, without their canals? The steam engines spread all over England are said to perform many times over the labor of the entire population of that country. The coal for those engines comes on their canals... Canals are the foundation of their wealth. Canals give industry its essence – the collecting of raw materials and the sending of the products of the factory to market.”⁵

As contemporary observers knew, transport was the key bottleneck. The mountainous terrain and lack of improved roads meant that the Lehigh, Schuylkill, and Wyoming valleys were poorly connected with the urban centers where concentrations of consumers lived. Moving coal by wagons was expensive and there were finite limits to the amount that could be transported in this manner. The Schuylkill and Lehigh rivers offered a more promising outlet, but their falls and variable water levels made it difficult for boats to travel downstream. Simply put, the coalfields of eastern Pennsylvania were not part of the trade hinterlands of cities like New York and Philadelphia.

⁴ Thomas Cooper, “Statement on Coal” from early nineteenth century, as cited in Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 1.

⁵ Josiah White, “English Industry” *The Democratic Press*, March 20, 1821, as cited in Norris Hansell, *Josiah White: Quaker Entrepreneur* (Easton, PA: Canal History and Technology Press, 1992), 56.

In seeking to develop Pennsylvania's coal resources, boosters directed their attention to solving the transport problem. Their efforts drew on a long history of popular support for improved transport networks in the mid-Atlantic. Philadelphia merchants were already petitioning the provincial Assembly in 1762 to investigate the west branch of the Susquehanna River to see if a connection could be established with the Ohio River. The American Philosophical Society recommended a canal linking the Schuylkill and Susquehanna rivers as early as 1771. In 1789, prominent Philadelphians including Robert Morris and David Rittenhouse formed the Society for Promoting Roads and Inland Navigation to encourage the improvement of transport infrastructure.⁶ Philadelphia printer, lawyer, and politician William Duane urged Pennsylvanians to demand their elected representatives support internal improvements in a series of letters to the *Aurora* newspaper in 1810.⁷ These efforts bore fruit as Pennsylvania had invested more capital in internal improvements than any government other than France by 1810.⁸

New Yorkers were also active proponents of internal improvements. The Empire State had invested more in its turnpikes by 1808 than any other state.⁹ In 1815 the State Assembly authorized construction of the Erie Canal and petitioned Congress for financial support and land rights.¹⁰ By contrast, transport boosters in other states were less

⁶ On early efforts to improve navigation, see: W. Bernard Carlson, "The Pennsylvania Society for the Promotion of Internal Improvements," *Proceedings of the Canal History and Technology Symposium* 7 (1988).

⁷ William J. Duane, *Letters, Addressed to the People of Pennsylvania Respecting the Internal Improvement of the Commonwealth; by Means of Roads and Canals* (Philadelphia: Printed by Jane Aitken, 1811).

⁸ This calculation included investments in banks. Thomas Childs Cochran, "Early Industrialization in the Delaware and Susquehanna River Areas: A Regional Analysis," *Social Science History* 1, no. 3 (1977): 291.

⁹ United States. Dept. of the Treasury, *Report of the Secretary of the Treasury, on the Subject of Public Roads and Canals* (Philadelphia: William Duane, 1808), 56.

¹⁰ *Memorial of the Commissioners of the State of New York, in Behalf of Said State; Praying the Aid of the General Government in Opening a Communication between the Navigable Waters of Hudson River and the Lakes*, (Washington: Printed by William A. Davis, 1816).

successful. Although Virginia exported some coal from its bituminous coalfields about twenty miles upriver from Richmond to Philadelphia and other cities, the variable flows of the James River limited the volume of the trade. Several Virginians petitioned the state to improve the James River in order to make it practical to deliver more coal. However, their efforts were rejected by the state government, which was controlled by eastern farming interests.¹¹ The role of the federal government in stimulating transport infrastructure was relatively minor during this period. Although it constructed some postal roads and commissioned some reports, state governments and private capital played more active roles.¹²

What animated these early boosters? While many of them were merchants and businessmen who stood to profit from increased commercial activity, it would be incorrect to see them as solely driven by the pursuit of profit. Political values were equally important. Many transport boosters hoped to create a strong and integrated nation out of a collection of young states, a particularly pressing task during the early years of the Republic. They believed that improved transport infrastructure would allow trade and communication between people, thereby binding them together. In seeking aid for the Erie Canal, New York commissioners noted: “[Canals] constitute improvements peculiarly fit for a republic. They contribute equally to the safety and opulence of the people, and the reputation and resources of the government. They are equally desirable in reference to the employments of peace, and the operations of war. In whatever light

¹¹ The James River was shallow and had variable flows. It could support small coal arks during certain parts of the year, but could not support large boats year-round. However, the James River did offer superior transport facilities circa 1800 compared to the Lehigh and Schuylkill rivers. The different political success of transport boosters in Virginia and Pennsylvania is well documented in Adams, *Old Dominion, Industrial Commonwealth: Coal, Politics, and Economy in Antebellum America*.

¹² See, for instance: United States. Dept. of the Treasury, *Report of the Secretary of the Treasury, on the Subject of Public Roads and Canals*.

they are viewed, they seem to combine the substantial glories of the most splendid and permanent utility.”¹³ Robert Fulton, the steamboat pioneer, put the matter more directly: “what stronger bonds of union can be invented than those which enable each individual to transport the produce of his industry 1,200 miles for 60 cents the hundred weight? Here then is a certain method of securing the union of the states, and of rendering it as lasting as the continent we inhabit.”¹⁴ Internal improvements were not just a commercial activity for early boosters, they were nation-building.

Although coal boosters failed to achieve great success before the 1820s, their efforts went beyond mere rhetoric. They mobilized financial and political resources, formed companies, introduced consumers to Pennsylvania’s anthracite coal, and laid the groundwork for the success of later endeavors. The history of their efforts demonstrates a sustained interest in developing the coal trade and highlights the central challenge of transport in the anthracite trade.

The Lehigh Coal and Mine Company was the first organization to bring anthracite coal from northeast Pennsylvania to Philadelphia. In 1791, Philip Ginder, described in various accounts as either a farmer or a hunter, allegedly tripped over a black stone while walking on Sharp Mountain. Suspecting that it might be coal, Ginder took a sample to Jacob Weiss, an area merchant familiar with anthracite. Weiss confirmed Ginder’s guess and began to contact his wealthy friends in Philadelphia to mine and market the coal. Together with his cousin Michael Hillegas (former Treasurer of the United States), his

¹³ *Memorial of the Commissioners of the State of New York, in Behalf of Said State; Praying the Aid of the General Government in Opening a Communication between the Navigable Waters of Hudson River and the Lakes*, 8.

¹⁴ United States. Dept. of the Treasury, *Report of the Secretary of the Treasury, on the Subject of Public Roads and Canals*, 123.

brother-in-law Charles Cist (a publisher), John Nicholson (Comptroller-General of Pennsylvania and a land speculator), and others, Weiss created the Lehigh Coal and Mine Company. Ginder bought some land near the area but was not actively involved in the new company.¹⁵

The company first purchased large amounts of land around the site of Ginder's discovery. Although coal would later be found in many other locations in the region, Ginder had stumbled upon a particularly fortuitous site. At Sharp Mountain (soon renamed Summit Hill), the Mammoth Vein, a belt of anthracite coal fifty to a hundred feet thick, rose to the surface. To extract the coal, miners only needed to clear the top level of dirt and then break off pieces of coal with picks and shovels. Because the site was above water level, drainage was not an issue. As a result, coal could be extracted without expensive shafts, tunnels, or water pumping systems. Moreover, massive quantities of coal were clustered in one site. Even as late as 1983, the area was still being mined by a subsidiary of Bethlehem Steel. Over its history, an estimated 250 million tons were removed from the site.¹⁶

While mining coal at Summit Hill was a relatively straightforward proposition, getting it to market was not. The mine was located nine miles from the Lehigh River, forcing the company to build a road between Summit Hill and Lausanne, the closest point on the river. While horse-drawn wagons could use the primitive road, drivers charged as much as \$4 per ton and the steepness of the grade prevented it from being used in icy

¹⁵ The best source on the early history of coal in the Lehigh region is: Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*.

¹⁶ Donald Sayenga, "The Untried Business: An Appreciation of White and Hazard," *Proceedings of the Canal History and Technology Symposium 2* (1983): 114.

weather.¹⁷ Once the coal reached the river, the company had to deal with the limitations of the Lehigh River. From Lausanne, the river fell more than 300 feet over the course of its 46-mile journey to Easton where it connected with the Delaware River. In many places it was very shallow and choppy, particularly during the summer months. It was possible to ship goods on arks—simple flat wooden boats that would only travel downriver and be sold as lumber with the rest of the goods—during times of high river flow (usually in the spring and fall). While this always involved a certain amount of danger and risk of lost goods, it was an established practice in the 1790s by lumbermen in the region.

The road and river enabled the Lehigh Coal and Mine Company to deliver coal to Philadelphia, but not on a competitive basis. After expanding its land holdings to more than 10,000 acres in 1798, the company accomplished little else and was basically moribund by 1800. The directors could not overcome the fact that imported coal and wood were cheaper and more convenient alternatives for Philadelphians when the transport costs were factored in. In addition, the company lost much of its vitality after the 1793 yellow fever epidemic killed as much as 20 percent of Philadelphia's population. Finally, the principals of the company were merchants who found their general business prospects failing during this time as New York replaced Philadelphia as the nation's premier port. As a result, they lacked the resources to develop the

¹⁷ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 12.

company's prospects further. Several of the Lehigh Coal Mine Company's founders went bankrupt and died poor, including Cist, Hillegas, Morris, and Nicholson.¹⁸

Over the next decade there were several efforts by entrepreneurs to continue to develop a coal trade. In 1806, attorney William Turnbull shipped several arks of coal down the Lehigh in an attempt to supply the coal needs of the Philadelphia waterworks. The waterworks could not get the coal to burn successfully, however, and the remaining coal was used as gravel in the street.¹⁹ In 1807, the Lehigh Coal and Mine Company leased its properties to two men named Rowland and Butland who intended to dig coal and iron ore. Their efforts did not succeed on a wide scale.

As the dramatic example of William Turnbull's coal being discarded as waste indicates, transport was not the only problem facing anthracite boosters. The physical qualities of anthracite also mattered. Anthracite coal contains an extremely high percentage of carbon (over 90 percent) that gives it a hard and shiny appearance, similar to obsidian. In fact, one of anthracite's first uses around the world was as a decorative stone in jewelry, a practice known in China and among Native Americans in northeast Pennsylvania. This high carbon content means that anthracite is difficult to burn. You cannot simply toss anthracite into a wood-burning fire and have it ignite, as is possible with bituminous coal.²⁰ On the other hand, anthracite has two important advantages over bituminous. One is that once it starts burning, it can create a hotter and steadier flame that is beneficial for home heating and forging iron. The second advantage is that it

¹⁸ Their economic misfortunes were aggravated by the failure of the Lehigh Coal Mine Company but not caused by them. The general loss of trade to New York was a much bigger factor. *Ibid.*, 13-16.

¹⁹ John P. Miller, *The Lehigh Canal: A Thumbnail History* (Allentown, PA: Printed for the Sesquicentennial of the Opening of the Lehigh Canal by Jibby Printing, 1979), 3.

²⁰ Bituminous coal contains a lower percentage of carbon than anthracite and therefore has a higher percentage of volatile gases facilitating ignition.

contains fewer impurities, such as sulfur, and therefore burns cleaner than bituminous.

As a result, it is much less polluting, has fewer ashes, and can forge iron more efficiently.

In 1800, this chemistry was not well understood. What people in Philadelphia knew was that anthracite was hard to burn, so they preferred working with wood, charcoal, or bituminous coal imported from England, Nova Scotia, or Virginia. The story of how Josiah White came to see the benefits of anthracite is instructive in this context. When he was operating an iron nail and wire factory in Philadelphia, he ordered some anthracite during the War of 1812. He and his workmen had attempted to ignite the coal unsuccessfully for several hours when they gave up in frustration. They shut the furnace door and left the factory. A worker who forgot his coat returned to the factory thirty minutes later and was shocked to find the furnace door glowing with heat. They had accidentally discovered the secret to burning anthracite—the air flow had to go through the coal rather than over it. With the anthracite lit, the men rushed back to the factory and were able to make four runs of iron wire from its heat. Josiah White became a committed advocate of anthracite from this point forward and estimated that it enabled him to produce iron wire for \$17 per ton, versus a cost of \$52 with bituminous coal.²¹ The higher heat levels of anthracite meant less coal was needed (five bushels of Lehigh coal versus twenty bushels of Virginia coal) and the smelting process required half the labor.²²

²¹ Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 50-51.

²² These savings are described in a testimonial produced for Jacob Cist by White and Hazard in November of 1814, as cited in: Hansell, *Josiah White: Quaker Entrepreneur*, 33.

Jacob Cist was the earliest booster who systematically sought to overcome the popular prejudice against anthracite coal.²³ If anyone's background could have prepared him better to be an anthracite advocate, it is difficult to imagine. Jacob's father was Charles Cist, one of the founders of the Lehigh Coal & Mine Company, and as a young man, Jacob had attended many of the company's business meetings. His uncle was Jacob Weiss, the man Philip Ginder had initially contacted to determine whether he had discovered coal. In addition, he had inherited his father's shares in the company and knew many of the other shareholders. Cist advanced his position in 1807 by marrying the daughter of Wilkes-Barre's richest merchant Matthias Hollenback, thereby becoming a partner in an extensive trading network that extended from New York City to Philadelphia. Moreover, his time in Wilkes-Barre exposed him to numerous blacksmiths, iron manufacturers, and farmers who had solved the challenges of using anthracite as an industrial and home heating fuel.²⁴

While Jacob Cist had been interested in anthracite from his early years, he made his most significant efforts to expand the trade during the War of 1812. As part of the hostilities, the British Navy had successfully blockaded most of the American seaports, including Philadelphia. As a result, Philadelphia craftsmen were experiencing soaring fuel costs. Virginia coal, which had been selling for thirty cents a bushel in 1812 had risen to over a dollar in 1813.²⁵ The sense of crisis was sufficient to encourage a group of

²³ Jacob Cist's role in introducing people to new energy sources is similar in many ways to the "agents of diffusion" described by Mark Rose in his analysis of the gas and electricity industries in Denver and Kansas City: Mark H. Rose, *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America* (University Park, Pa.: Pennsylvania State University Press, 1995).

²⁴ For more on Jacob Cist, see: Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*.

²⁵ Ibid., 24. While a bushel is a measure of volume, not weight, it corresponds to roughly eighty pounds. There are about 28 bushels in a ton of 2,240 pounds, the usual weight for anthracite shipments. In the early

Philadelphia manufacturers, including the prolific inventor Oliver Evans, to form The Mutual Assistance Coal Company of Philadelphia for the Promotion of Manufactures. This organization sought to ensure steady deliveries of coal to the city's craftsmen. Cist used this fuel crisis to expand his coal operations and seek to develop a permanent market in the Quaker City. He formed partnerships with Isaac Chapman, Charles Miner, and John Robinson to collaborate in the venture.

With his personal connections, Cist easily obtained a lease from the dormant Lehigh Coal Mine Company to mine coal and use its timber lands.²⁶ From a transport perspective, Jacob Cist and his partners did little to innovate on existing practices. In 1813, Cist sent coal to market in Philadelphia from the Wyoming Valley using wagons. The coal sold for a dollar per bushel, although its transport cost of \$20 per ton meant that little profit was made (there are approximately 28 bushels in a ton). In the following years, the partners used the old road of the Lehigh Coal Mine Company to transport coal from the Summit Hill mine to the banks of the Lehigh River, where the coal was shipped to market via arks. Cist hoped to achieve costs of \$7.50 per ton shipped along the river, but his actual expenses ended up being \$10.50, 90 percent of which were transport-related (\$1 for mining, \$3 for hauling, \$5.50 for arking, \$1 for provisions).²⁷ For comparative purposes, an 1816 report from the U.S. Senate noted that the cost of shipping a ton of goods 3,000 miles from Europe was only \$9.00, or \$.50 less than the

history of coal when smaller amounts were shipped, companies recorded the amounts in bushels, and switched to measuring tons when the amounts increased. Households generally purchased coal by the bushel.

²⁶ In return for an ear of corn a year (payable upon request), Cist got permission to use the properties as long as he agreed to ship 5,000 bushels a year.

²⁷ Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 33.

110-mile journey from the Summit Hill mine to Philadelphia.²⁸ Because of the scarcity of coal in Philadelphia due to the War of 1812, Cist, Chapman, and Robinson were able to sell the Lehigh coal for nearly a dollar a bushel, making a profit of \$1,650 from selling 100 tons for \$2,700.²⁹

Chapman coordinated the hiring of laborers to dig coal and teams to transport it to the river. He also worked to establish a settlement at Mauch Chunk (just north of Lausanne), believing that a community of trained craftsmen would help to develop the coal trade. Jacob Cist focused on marketing. He worked extensively to encourage Philadelphians to use anthracite coal in homes and factories and employed a multi-prong strategy. For example, he hired Peter Yarrington, a Wyoming Valley blacksmith, to visit Philadelphia iron works and instruct the smiths on techniques for using anthracite. He published circulars in Philadelphia newspapers describing the benefits of anthracite and encouraging its use. He also engaged in scientific studies expanding the base of knowledge about stone coal, for example, by mapping the coal seams and providing estimates of the available reserves.³⁰

Cist's marketing efforts were critical to the later adoption of anthracite coal, but his work did not translate into personal financial success. When the War of 1812 ended, the price advantage of anthracite disappeared. Most Philadelphia craftsmen returned to burning Virginia bituminous once it returned to the pre-war level of \$.30 per bushel (approximately \$8.40 per ton, less than the transportation costs of Lehigh coal). Cist and Chapman soon abandoned their efforts and Cist focused on his mercantile business in the

²⁸ George Rogers Taylor, *The Transportation Revolution, 1815-1860* (New York: Rinehart, 1951), 132-33.

²⁹ Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 33.

³⁰ *Ibid.*, chapter 3.

Wyoming Valley. He would continue to be interested in anthracite ventures until his premature death at age 43 in 1825.

By 1815, there had been several efforts to introduce anthracite coal, but they had not been financially successful. This early period reveals several lessons. First, there were numerous anthracite boosters. These men not only sought personal profit, they also hoped to improve the position of the young nation. Second, the efforts to develop a coal trade occurred in a world of energy abundance, not scarcity. While the war of 1812 created a temporary energy shortage that was advantageous to anthracite boosters, most of the time people had sufficient supplies of firewood, water, coal, and muscles to meet their needs. Anthracite was seen as an opportunity to replace other sources, not as a social necessity. Third, the cost of transport was a significant hindrance that early boosters failed to overcome. Coal could be shipped more cheaply to Philadelphia from Britain, Nova Scotia, and Virginia than the Lehigh Valley. As Cist's account books show, 90 percent of the cost of anthracite in Philadelphia was for transportation, and only 10 percent was for mining. Finally, the particular properties of anthracite coal created an additional challenge for boosters. Consumers needed to redesign furnaces and learn new techniques to burn anthracite. Marketing efforts by anthracite merchants during this period, therefore, played an important role in laying the groundwork for the future success of the trade.

The Lehigh River and the First Transport Revolution, 1817-1825

In 1820, Josiah White and Erskine Hazard succeeded where so many others had failed. That year, they were able to improve the river enough to deliver 365 tons of

anthracite to Philadelphia. While the movement of a few hundred tons of coal was hardly revolutionary, it marked the beginning of a new energy landscape in the mid-Atlantic. By investing in infrastructure to lower the cost of moving coal from the Lehigh Valley to Philadelphia, Josiah White, Erskine Hazard, and the laborers of the Lehigh Coal & Navigation Company eliminated the most significant obstacle to the consumption of anthracite coal on the eastern seaboard. Coal was now part of the energy hinterland of Philadelphia.

Josiah White was born in Mount Holly, New Jersey in 1781 to a devoutly Quaker family of moderate means. He received a rudimentary education, but was always far more interested in practice than theory, and his practical abilities were impressive. He was apprenticed to a Philadelphia hardware store owner at the age of 15 and within a couple years he was running the store himself. He soon opened his own store and by the age of 28 had amassed a small fortune of \$40,000. He planned to retire as a gentleman farmer, but Catherine Ridgeway, his young wife, died. Grief-stricken, White spent the next two years traveling. When he returned to Philadelphia in 1809, he married Elizabeth White (no relation).

In 1810, White decided to re-enter the business world, a decision that would have far-reaching effects on the development of the anthracite trade. In that year, he purchased the Schuylkill Falls from Robert Kennedy for \$14,000.³¹ The deal included property on either side of the Schuylkill River and a charter to dam the river and charge tolls for passage. White described a sense of financial opportunity and civic responsibility as important motivators: “If I succeeded, it would lead to a similar improvement in the

³¹ This property was located about a mile north of the current Fairmount Dam.

interior of Pennsylvania which would be of great public good. While the water power & the Falls would make it a profitable investment to me & fully as well as to invest my capital elsewhere.”³²

White’s property along the Schuylkill was a site of technological innovation and financial strain. The challenge was daunting. In 1810, no American river the size of the Schuylkill had been successfully dammed. White tried a number of designs before discovering that an angled dam would bear the water pressure without folding.³³ Building the dam, however, cost White almost all of his fortune. Even though the technical achievement was widely regarded by his contemporaries, it did not generate a profit. One of his plans was to sell water power from the dam to industrial enterprises, but he found no customers. He also sought to earn money by charging a \$.50 toll—the maximum allowable by law—on boats using his lock. These charges generated a firestorm of criticism among boating men who had been accustomed to free use of the Schuylkill.

At the same time he was building the dam, White also established two factories on the property, one to manufacture iron nails and the other to produce iron wire. His innovative ideas soon drew the interest of Erskine Hazard who became his partner in 1811. The men met at the house of Ebenezer Hazard, Erskine’s father. Ebenezer Hazard was the first postmaster of the United States and hosted many gatherings of Quakers. Seven years younger than Josiah, Erskine shared his mechanical aptitude and business

³² Josiah White, *Josiah White's History, Given by Himself* (Philadelphia: Press of G.H. Buchanan Company, 1909), 12-13. Note: White’s memoirs include some idiosyncratic abbreviations and misspellings which I have corrected.

³³ Richard Richardson, *Memoir of Josiah White. Showing His Connection with the Introduction and Use of Anthracite Coal and Iron, and the Construction of Some of the Canals and Railroads of Pennsylvania, Etc* (Philadelphia: J.B. Lippincott & Co., 1873), 23-24.

interests, and also had the benefit of formal education.³⁴ Erskine attended Princeton and had published original scientific research on electricity in 1809. Erskine's brother Samuel was the editor of the widely circulated journal *Hazard's Register*.

White and Hazard created several innovations at the Whitestown Manufacturing Company, as the factories were known. White took out a patent in 1810 for a new method of rolling nails and after Hazard visited France to witness new methods of producing wire, they filed a patent on new techniques in 1812. They developed a new model for an iron canal boat that worked, although it was not financially successful. After a pedestrian bridge over the Schuylkill was destroyed by a flood, White and Hazard erected the first wire suspension bridge in America in 1816.³⁵ Most importantly, their work at the factories exposed White and Hazard to the benefits of using anthracite coal in manufacturing processes.

Despite White and Hazard's clear inventive genius, the Whitestown Manufacturing Company was only moderately successful, in part due to the general economic decline of the period. Then disaster struck in April of 1815. A fire broke out and the factories burned to the ground, forcing White to go \$20,000 into debt and to sell nearly half of the property.

White and Hazard also turned their attention in these early years to the development of the Schuylkill River. Philadelphians had been interested in improving the Schuylkill since the time of William Penn. They knew that improved river transport would enhance the Quaker City's position as the nation's trading center and give its manufacturers access to upstream markets. Benjamin Franklin was part of a group that

³⁴ White would lament his lack of interest in formal learning later in his life. *Ibid.*, 11.

³⁵ Hansell, *Josiah White: Quaker Entrepreneur*, chapter 3.

led an effort in the 18th century to remove large rocks from the middle of the river, but financial limitations meant they only improved a small section. In the winter of 1812-1813, White and Hazard presented petitions to the Pennsylvania legislature requesting a charter to improve the river and charge tolls for navigation. However, the unpopularity of the toll charges White was charging at the Schuylkill Falls created a strong backlash among boatmen towards his proposal. They noted that he had charged the maximum toll allowable by law at the Schuylkill Falls and feared he would do the same along the entire length of the river. In addition, even though White and Hazard envisioned shipping coal along the Schuylkill, Frederick Fraily, a state Senator, denied there was coal along the river, just a black rock that would not burn.³⁶

The Pennsylvania legislature authorized the creation of the Schuylkill Navigation Company in 1815. White became one of the largest shareholders of the corporation, and hoped to be appointed a manager, based on his advocacy for improving the Schuylkill and his proven record in river improvements. However, at the first meeting of the board of directors, his opponents prevailed and White was denied an active role in the development of the Schuylkill, being relegated to an oversight role as a commissioner. Over the next two years, White and Hazard offered several proposals to the directors of the Schuylkill Navigation Company regarding the delivery of coal, but these were rejected. In a rage, White is reported to have exclaimed: “This ends our using the Schuylkill! I’ll go to another region! The ... Lehigh ... I’ll make the Lehigh a rival to the Schuylkill.”³⁷

³⁶ White, *Josiah White's History, Given by Himself*, 15.

³⁷ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 22. Original citation is to Miller, *The Lehigh Canal: A Thumbnail History*, 6.

While the above quotation is most likely apocryphal, it is a good approximation of what happened. White and Hazard turned their attention to the Lehigh River and its coal resources. In December of 1817, White surveyed the river along with his stonemason William Briggs and George Hauto, a flamboyant man who often visited White and Hazard to discuss engineering matters. Short on cash and with little backing, White had to rent a horse and borrow the surveying equipment that had been used in 1791 by the ill-fated Delaware and Schuylkill Canal Company. After surveying the river for a week, White returned convinced that he could make the necessary improvements to ensure a regular coal trade. He, Hazard, and Hauto decided to form a partnership.

Few people shared White's confidence, a fact that worked for and against the partners. On the positive side, it made obtaining a corporate charter much easier. Corporate charters had to be approved by a vote of the state legislature at the time, making them rare and valuable. Hauto wrote the proposed legislation, asking for extensive rights to the river, and then argued the case before the legislature in German, the main language of the assembly at the time. The charter was granted without much debate, largely because everyone expected them to fail. According to White's recollection, there had been at least seven charters granted to improve the Lehigh over the last half-century.³⁸ As one legislator is reported to have expressed it, the men were "given permission to ruin themselves."³⁹ The broad corporate privileges given to the partners, in particular the right to ship *and* mine coal, would later be hotly contested, but it caused little debate at the time. In addition, the partners were easily able to obtain a

³⁸ These were passed in 1771, 1791, 1794, 1798, 1810, 1814, and 1816. Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 13.

³⁹ *Ibid.*, 38.

lease from the dormant Lehigh Coal Mine Company to use its properties as no other parties were seeking to develop the Lehigh region.⁴⁰

On the other hand, the lack of faith in White's endeavor made it much more difficult to raise capital. In his memoirs, he describes the reception of prominent Philadelphians to his proposal, which ranged from polite refusals to men who signaled the end of the discussion by picking up the newspaper.⁴¹ To make their project more attractive, the partners pursued several strategies, including hiring independent engineers to survey the lands and evaluate the proposal, splitting the company into a coal mining company and a transportation company, and agreeing that investors would receive dividends before the partners.⁴² White and Hazard had also expected Hauto to help them raise money from his wealthy friends in New York and Baltimore. This did not happen. White and Hazard soon discovered that Hauto was widely considered to be a confidence man and swindler and eventually forced him out of the partnership.⁴³

The difficulty in attracting investors was not because of a broader social resistance to transport infrastructure. For example, the Schuylkill Navigation Company had raised \$500,000 very quickly two years earlier.⁴⁴ Instead, investors worried about the difficulty of improving the Lehigh and whether there was a sufficient market for anthracite. Moreover, the Lehigh Valley was less densely settled than the Schuylkill region, which meant there were fewer potential investors. As John Majewski has shown,

⁴⁰ The deal was similar to the one signed by Jacob Cist earlier. In return for an ear of corn per year, White obtained a 20-year lease on the properties as long as he delivered 40,000 bushels of coal per year after three years. *Ibid.*, 31.

⁴¹ White, *Josiah White's History, Given by Himself*, 24-26.

⁴² Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 38-40.

⁴³ White, *Josiah White's History, Given by Himself*, 42-45.

⁴⁴ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 127.

Pennsylvania farmers were large investors in transport infrastructure because they hoped to improve the value of their land and their access to market, not because they expected the company to return dividends.⁴⁵

White and Hazard finally got capital investors when John Stoddardt agreed to invest \$10,000. Stoddardt was a successful land speculator, and his backing encouraged several others to join him. Soon afterwards, White and Hazard had raised \$100,000 and formed the Lehigh Coal Company and the Lehigh Navigation Company in the fall of 1818.⁴⁶ In 1821, the two companies were merged to form the Lehigh Coal & Navigation Company.

With capital, a corporate charter, and the rights to coal properties in the Lehigh Valley, White and Hazard turned their attention to improving the river and road from Summit Hill. At this point, White's practical mind turned to great advantage. The partners started simple. Because there was little incentive to ship goods upriver (as the upper Lehigh Valley was sparsely settled and had few consumers) they devoted their attention to improving downriver navigation for coal arks. Their primary strategy was to funnel the flow of the river towards the middle, thereby creating a deeper channel for arks, and to remove obstacles like large rocks from the middle.

White and thirteen workers traveled to Lausanne in August of 1818 and began work. They removed large rocks from the middle of the river and built stone walls that created a deeper channel at wide points. By the end of 1818, there were over three

⁴⁵ John D. Majewski, *A House Dividing: Economic Development in Pennsylvania and Virginia before the Civil War* (Cambridge, UK: Cambridge University Press, 2000), 13.

⁴⁶ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 39.

hundred men working on the river.⁴⁷ White estimated that this was the largest group of men working on a public improvement project in Pennsylvania at the time.⁴⁸

Clearing stones and forming channels made navigating the river easier, but could not address the challenge of irregular water flow. Local residents had told White that the water never dropped below a certain point on a rock in the river. The next year a severe drought lowered the water level a foot below this line.⁴⁹ In response, White decided to use the system of pond freshets to ensure adequate water depth. Sometimes used by lumbermen, pond freshets involved creating a temporary dam that would build up a large pool of water. When the dam was released, lumber could be floated downstream on the long wave of high water that had been gathered. In 1819, White directed his workers to create a series of dams along the Lehigh that would allow shipments of coal regardless of the river's water level.

While the artificial dams developed by lumbermen were often temporary, White needed a more permanent system. Therefore, he developed an innovative lock mechanism that made it simple to trap and release the water. Using hydrostatic pressure, the gates could be opened and closed by pressing a single lever, allowing a boatman to release the boats and water and reset the gates after the last ark had passed. If a curious passerby asked what the men were building, they responded that the gates were "bear traps," an early form of trade secrecy. The name stuck, and White filed for a patent on his design in December of 1819.⁵⁰

⁴⁷ Ibid., 40-41.

⁴⁸ Eleanor Morton, *Josiah White, Prince of Pioneers* (New York: Stephen Daye Press, 1946), 118.

⁴⁹ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, (Philadelphia: William S. Young, 1840), 10.

⁵⁰ White, *Josiah White's History, Given by Himself*, 36.

The partners also knew it was essential to improve the road from Summit Hill to Lausanne. White re-graded the road so that it descended its entire length without a single rise. He claimed that this was the longest such road in America at the time.⁵¹ In addition, he redesigned the wheels of the wagons used to carry the coal. He installed wheels of varying width and coated them with iron. Thus equipped, the wagon wheels flattened and improved the road with use instead of creating ruts. These changes to the road allowed White to lower the cost of transporting coal from the mines to the river from the \$4.00 per ton paid by Cist and Chapman to 62.5 cents by the early 1820s.⁵² In addition, White and Hazard turned the fledgling community of Mauch Chunk (just north of Lausanne) into a company town. The active managers of the company operated from Mauch Chunk beginning in the early 1820s while the financial management was centered in Philadelphia.

It is easy to celebrate White and Hazard's vision and technical management, but without hundreds of hard-working men who have been lost in the historical record, the river could not have been improved. The labor conditions were basic, regardless of whether the work was performed in the river, in the mine, or on the road. The main tools were shovels, picks, dynamite, wheelbarrows, and most important, human muscle. To create the bear trap locks, the men spent several hours a day up to their waists in water, with a hole cut in the toe of their boots so that the water would drain out. The river banks were largely unsettled, so White constructed a series of flat boats that served as a floating camp for the workers. As they completed any section of the river, they floated the boats

⁵¹ Ibid., 35.

⁵² Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 53.

down river a little ways, anchored them, and began working again. Workers considered it a significant improvement in working conditions when primitive mattresses were purchased a few years later.⁵³

Work relations seem to have been relatively smooth, as there were no reported interruptions, although there were clearly underlying tensions. White adopted the dress of the workers (red flannel shirt, buckskin coated pants, boots with holes in the toe) and worked in the river with the men. However, the managers took several precautions that indicate separations between themselves and the workers. First, they made clear that all wage checks had to be signed by at least two of the managers, so that a group of workers could not accost one of the managers in the forest and force him to sign a check. Second, the managers instilled “cob” laws borrowed from sailing culture. Workers who took more food than they could eat, ran “in any way uncivil” to their meals, or misbehaved in other ways, were to be coked, or spanked with a paddle.⁵⁴ White claimed the workers requested these laws to be put in place, although this statement seems unlikely to be true.⁵⁵

We do not know a lot about the laborers themselves. Commentators at the time were quick to make distinctions between the thrifty, hard-working Yankee or German laborers and the dirty, drinking Irish hands, a common trope of the mid-nineteenth century. For instance, Anne Royall, a traveler who recorded her journeys, wrote: “But the Teagues, poor fellows, they are strung along the canal, scarcely alive, stupid from

⁵³ Richardson, *Memoir of Josiah White. Showing His Connection with the Introduction and Use of Anthracite Coal and Iron, and the Construction of Some of the Canals and Railroads of Pennsylvania, Etc.*, 58.

⁵⁴ White, *Josiah White's History, Given by Himself*, 28.

⁵⁵ According to White, “In the beginning our hands wasted provisions. Some of them, perhaps having had experience aboard maritime ships, asked our consent to make a few cob laws to aid us in checking these and other impositions.” As quoted in Hansell, *Josiah White: Quaker Entrepreneur*, 48.

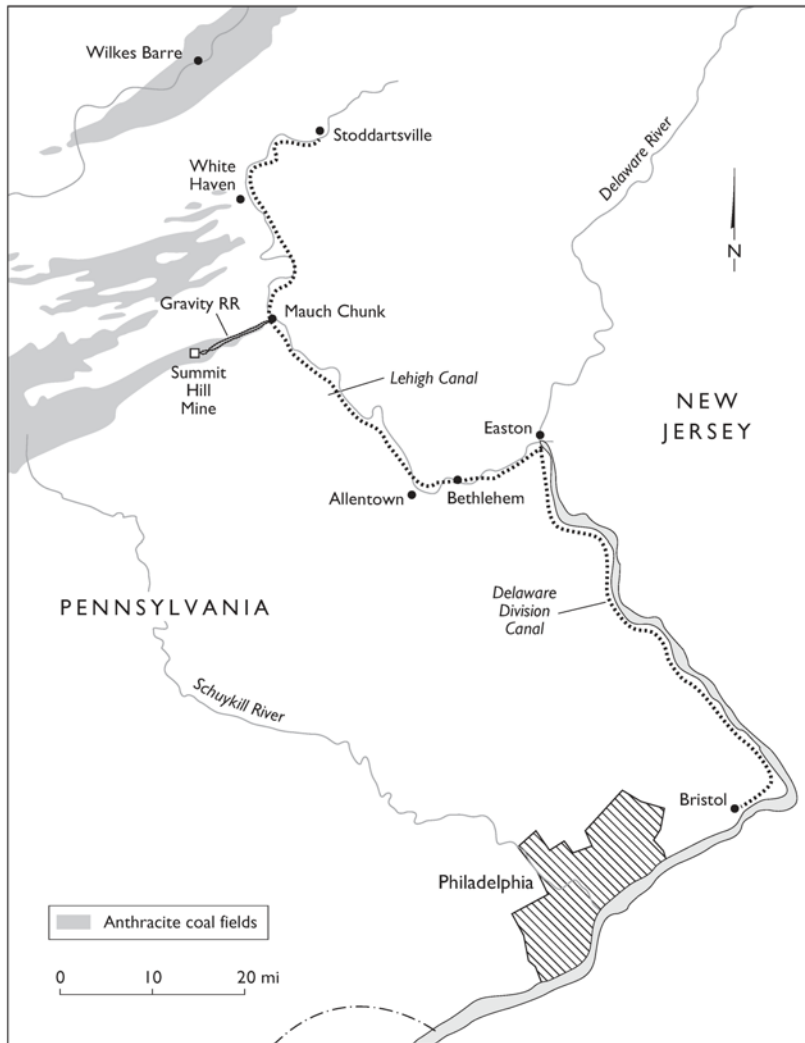
drink... I have been informed that they generally live about 18 months after coming to this country, and work and drink most of the time. They care little about eating, provided they get whiskey.”⁵⁶ Without doubt these sentiments say as much about 19th century attitudes as the workers themselves. We know that they must have worked very hard under difficult circumstances, facing dangers from accidents, the elements, and disease.

By the fall of 1820, the river was sufficiently improved that the company could send its first 365 tons of coal to market. Eight of eleven bear trap locks had been completed along with several wing-dams and miles of stone walls. While there were several setbacks during construction—ice floods during the winters destroyed some of the work and a series of slate ledges proved so difficult to improve that they forced White to invest an additional \$40,000 in the company—the fast pace of work and low cost was remarkable. While it would take over ten years and more than two million dollars to create a functioning canal along the Schuylkill River, the Lehigh Coal & Navigation Company had created a system that made it possible to deliver coal at competitive prices in two years and for less than \$200,000.⁵⁷

⁵⁶ As cited in Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 27.

⁵⁷ White and Hazard had not created a full canal system. Their first improvements were a descending-only system that did not allow boats to travel upriver. When they decided to build a full canal along the river, it cost several hundred thousand dollars. These developments are discussed later in this chapter.

Map 1.1: Lehigh Canal



Transforming the built environment of the Lehigh River made it possible for White and Hazard to deliver anthracite coal to Philadelphia where they could profitably sell it for \$8.40 a ton, about the same price as Virginia coal. However, shipping coal to market and selling it were two different things. As the company itself noted, the first 365 tons were only disposed of “with difficulty.”⁵⁸ The company had to overcome some of the prejudices against anthracite coal that stymied earlier boosters. In addition to

⁵⁸ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, 11.

working with craftsmen, White & Hazard also hoped to develop a domestic trade using anthracite for home heating.

The domestic market was attractive both because of its large potential and the increasing price of firewood in cities such as Philadelphia, New York, and Boston. As early as 1744, Benjamin Franklin observed that firewood was getting more expensive and had to be fetched from further away, leading him to develop a stove that would heat houses more efficiently.⁵⁹ Although shipping lumber down the Schuylkill and Delaware rivers from longer distances over the next several decades ensured that no acute shortage had occurred by 1820, firewood prices had steadily increased. Given that a poor family required at least 2.5 cords of wood per winter while a wealthy family often used more than 20, it was no surprise that coal boosters saw the potential of the domestic market.⁶⁰ Several contemporary writers noted the increasing price of firewood and worried that dwindling supplies would present a limit to urban growth.⁶¹

However, the difficulty of burning anthracite was a significant hindrance to its adoption. Consumers had to invest in a specially designed stove or grate and alter their heating and cooking practices. Because burning anthracite in a stove meant abandoning the pleasant flame of an open hearth, many objected on aesthetic grounds. White and Hazard undertook several efforts to overcome these challenges. First, White had his wife Elizabeth maintain a burning anthracite fire in their home at all times so that people could

⁵⁹ Sean P. Adams, "Warming the Poor and Growing Consumers: Fuel Philanthropy in the Early Republic's Urban North," *Journal of American History* 95, no. 1 (2008).

⁶⁰ A cord of wood was a stacked pile of wood four feet wide, eight feet long, and four feet high. For estimates of fuel consumption see: "Fuel Savings Society," *Hazard's Register*, August 20, 1831; "Anthracite Coal, Versus Wood," *Hazard's Register*, November 15, 1834; Adams, "Warming the Poor and Growing Consumers: Fuel Philanthropy in the Early Republic's Urban North."

⁶¹ "Exposition," *Miners' Journal*, April 2, 1831.

see it in operation.⁶² Second, both White and Hazard wrote articles to newspapers extolling the value of anthracite in the home. In an article appearing in *The Democratic Press*, White noted that Lehigh coal was better than wood for family use, as it “burns with a more durable fire, is beautiful in an open parlour grate, and does not foul the chimney.”⁶³ Third, the company advertised anthracite with pamphlets that gave testimonials by homeowners and craftsmen about the benefits of Lehigh coal.⁶⁴

Their efforts had some, but not complete success. The company increased its shipments to 1,073 tons in 1821, 2,240 tons in 1822, and 5,823 tons in 1823. However, at the beginning of the 1824 season, there were still over 1,000 tons unsold in Philadelphia warehouses. The company’s board of directors recommended that the company ship 2,000-3,000 tons that year. White and Hazard objected strenuously. They argued that customers needed to be assured that a full supply would always be available in order to have confidence to switch over. Supply, they believed, needed to drive demand. White and Hazard carried the day, and the company delivered 9,451 tons of anthracite in 1824, lowering the price to \$7.00 per ton.⁶⁵

According to White, the winter of 1824-1825 was the turning point in the history of anthracite coal consumption. He credited the decision to flood the market with anthracite for the success because it reassured consumers.⁶⁶ While this was an important

⁶² Elizabeth lived in Philadelphia with the couple’s children during the early 1820s. Josiah spent most of his time in Mauch Chunk and along the river. Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 52.

⁶³ “On the Use of Lehigh Coal,” *The Democratic Press*, March 21, 1821, as cited in *Ibid.*, 49.

⁶⁴ Lehigh Coal and Navigation Company, *Facts Illustrative of the Character of the Anthracite, or Lehigh Coal, Found in the Great Mines at Mauch Chunk, in Possession of the Lehigh Coal and Navigation Company with Certificates from Various Manufacturers, and Others, Proving Its Decided Superiority over Every Other Kind of Fuel* (New York: Gray & Bunce, 1825).

⁶⁵ White, *Josiah White's History, Given by Himself*, 52.

⁶⁶ *Ibid.*

factor, White and Hazard were not the only ones driving anthracite demand. If consumers were worried about a steady supply of anthracite, they would have felt far more secure because the opening of the Schuylkill Canal in 1825 meant that two canal systems were delivering coal. New designs of stove grates by iron manufacturers also made it cheaper and easier for homeowners to burn anthracite. Finally, there were timber shortages in 1825 that caused high prices for firewood.⁶⁷

By 1825, the prospects for the Lehigh Coal & Navigation Company and the anthracite trade were extremely promising. This was a large relief to White & Hazard as raising money to complete the bear-lock navigation system in the early 1820s had been difficult, requiring them to offer favorable terms to investors and apply their own capital. Once the consumption of anthracite in homes had gained considerable momentum, it made a significant difference to the company's finances. The first dividends were sent to investors in 1822 and by 1824, White and Hazard received dividends as well.⁶⁸ The energy landscape of the mid-Atlantic had been altered in a way that made ever-increasing supplies of fossil fuels a possibility.

System Expansion, 1825-1840

Energy landscapes are not static. The creation of descending-only navigation on the Lehigh River opened the market for anthracite coal. In the years following 1825, however, increased consumer demand threatened to exceed the capacity of the bear trap lock navigation system. After shipping over 9,000 tons in 1824, the company delivered

⁶⁷ Ronald Filippelli, "The Schuylkill Navigation Company and Its Role in the Development of the Anthracite Coal Trade and Schuylkill County, 1815-1845" (M.A. Thesis, Penn State University, 1966), 36.

⁶⁸ As part of their efforts to acquire capital, White and Hazard agreed not to award themselves dividends until the investors received 3%. Jones, *The Economic History of the Anthracite-Tidewater Canals*, 18.

28,393 tons in 1825 and 31,280 in 1826.⁶⁹ The anthracite market showed no signs of slowing. For example, Floyd Bailey, a New York coal merchant, signed an agreement with the Lehigh Coal & Navigation Company to deliver 10,000 tons of anthracite in 1825 and increase the shipments by 7,000 tons every year.⁷⁰ The system of bear trap locks could ship several thousand tons of coal per year, but not hundreds of thousands of tons. Supply and demand could only operate synergistically if enhancements to the energy landscape of anthracite flows could deliver ever-increasing quantities of fossil fuel energy.

Wood was the primary limitation of White and Hazard's bear trap navigation system. Coal was delivered to markets on wooden arks that could only be used once. Each ark was built by workers at Mauch Chunk and loaded with about sixty tons of coal and floated to Philadelphia. In Philadelphia, the boatmen broke up the arks and sold the wood as lumber.⁷¹ This required substantial amounts of wood. Each ark was 16-18 feet wide and 20-25 feet long. In 1827, the company reported that the arks used to ship coal that year would have stretched more than fifteen miles if placed end to end, requiring more than seven million feet of lumber.⁷² While the company had access to large forest tracts in the upper Lehigh Valley, the use of wood in arks was already contributing to deforestation in the area. White feared that if they did not develop ascending navigation,

⁶⁹ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 52.

⁷⁰ Ibid. This contract was never fulfilled as Floyd Bailey went out of business. However, the terms of the contract make clear that coal transporters and merchants expected demand to continue to increase.

⁷¹ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, 14. The boatmen kept the iron nails and walked back up the river to start the process once again.

⁷² Richardson, *Memoir of Josiah White. Showing His Connection with the Introduction and Use of Anthracite Coal and Iron, and the Construction of Some of the Canals and Railroads of Pennsylvania, Etc.*, 68.

which would allow them to reuse canal boats, they would soon run out of wood.⁷³

Moreover, a large canal could support canal boats capable of carrying far more coal than the 60-ton arks.

In 1826, White and Hazard turned their attention to revamping their entire infrastructure system. First, they replaced the road from the Summit Hill mine with a gravity railroad. This was a major technological accomplishment and one of the longest railroads in the world at the time. White claims to have planned this project as early as 1818, but could not justify the capital expenditure until shipments increased.⁷⁴ In 1826, White presented his plan to the Board of Directors, even creating a 100-foot scale model. The company hired William Strickland to review the proposal. Strickland was one of the few Americans experienced with railroad improvements, since he had been sent to Europe to study roads, canals, and railroads the previous year by the Pennsylvania Society for Internal Improvements. He approved the plan and the company started work the following winter.

Workmen installed over twelve miles of track—nine miles from the river to the mine, and then nearly four miles of branching lines inside the mine. White chose a relatively cheap method of construction, laying wooden rails across wooden ties and covering the wooden rails with iron, abandoning the British practice of fixing rails to granite blocks. Each railroad car could carry a ton and a half of coal, and descended the entire length by gravity. Horses and mules rode down in empty cars and then hauled the empty cars back up the tracks. To increase efficiency, the animals were fed on the

⁷³ White, *Josiah White's History, Given by Himself*, 59.

⁷⁴ White's decision to make the road bed descend its entire length in 1818-19 is indication of his forward-thinking outlook, since it enabled a gravity railroad to be constructed.

descending journey leading some to quip that these were the first railroad dining cars.⁷⁵⁶⁶

Each team could complete two and a half trips in a day. The gravity railroad was completed in under four months at a cost of \$38,726. It immediately paid dividends by lowering the cost of transportation of coal from mine to river to 22 cents per ton.⁷⁶

The gravity railroad was a major technological accomplishment and soon became a tourist attraction. Passengers could ride the line in specialized cars, and many flocked to Mauch Chunk for the privilege. The cars went as fast as 30 miles per hour, a dizzying speed at the time that few people had ever experienced before.⁷⁷ Unfortunately, at this speed the horses and mules became sick, so the cars were usually run more slowly for coal deliveries.⁷⁸

The company next turned its attention to creating a canal that would facilitate ascending and descending navigation. Although canals may seem simply like large ditches, they were complex technological systems and among the largest undertakings of the early nineteenth century. Canals involved significant engineering knowledge and skills, including “locks, feeder canals to provide water in the highest part of the canal, dams to protect the canal from spring floods, and aqueducts and tunnels to overcome valleys and mountains.”⁷⁹ The loose soil along the Delaware and Lehigh rivers created an additional challenge for canal builders. In order to maintain the water depth in the channel, workers needed to line the canal with planks and hydraulic cement. Engineers

⁷⁵ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 30.

⁷⁶ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 60.

⁷⁷ William H. Shank, *The Amazing Pennsylvania Canals* (York, PA: American Canal & Transportation Center, 1973), 63.

⁷⁸ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 16.

⁷⁹ Carlson, "The Pennsylvania Society for the Promotion of Internal Improvements," 180-81.

on the recently completed Erie Canal had worked out solutions to some of these problems, but the practice of building canals in America was still in its infancy in 1825.

Canvass White, an engineer on the Erie Canal and no relation to Josiah, was hired by the company in 1827 to direct the efforts. Under his guidance, the workers constructed a navigation that was a combination of canal (36 miles) and slack-water (10 miles), with a tow-path along the entire length.⁸⁰ The canal was sixty feet wide on the surface, forty-five feet wide on the bottom, and five feet deep. There were fifty-six locks between Mauch Chunk and Easton, varying in height from six to nine feet. The total fall over this stretch was 355 feet. To ensure that the canal could support large shipments of coal, Josiah White insisted that the locks be big enough to allow two boats of 120-ton capacity to pass at one time. The locks were 22 feet wide and 100 feet long, much larger than typical canal locks.⁸¹ The work took two years to complete and Canvass White calculated that the total cost was \$781,303.⁸²

The gravity railroad and canal system significantly expanded the quantities of coal the company could ship to markets. However, the company did not immediately feel the benefits of their improvements to the Lehigh River because there was not a comparable upgrade to the Delaware River. Most of the year, the Delaware River could float small arks, but its water level was not always sufficient to handle 120-ton canal boats. White and Hazard had long recognized this situation. As early as 1823 they

⁸⁰ Slack-water navigation meant that the boats floated in the main channel of the river, as opposed to canal navigation, where boats traveled in-between two artificial banks. Slack-water navigation was cheaper to build, but could only be implemented in places where the river was calm and deep along the edges.

⁸¹ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 26.

⁸² Richardson, *Memoir of Josiah White. Showing His Connection with the Introduction and Use of Anthracite Coal and Iron, and the Construction of Some of the Canals and Railroads of Pennsylvania, Etc.*, 77-79.

petitioned the state government to allow them to improve the Delaware River. Their proposal was rejected for several reasons. White's ambitious plan called for a canal big enough to handle 150-ton steam-powered ocean-going vessels led many to doubt the credibility of the proposal. Other users of the river were worried that White would charge high tolls as he had on the Schuylkill River. Finally, this was the hey-day of canal building, and many thought the state should build the canal itself so as to reap the profits.⁸³

In 1827, Pennsylvania lawmakers decided to construct a canal along the Delaware River as part of the Pennsylvania canal system. However, the state engineers decided to pursue a different strategy than White and Hazard hoped. Instead of creating a large canal able to handle heavy coal boats, they decided to follow the European model of small canals. William Strickland's influential 1826 report on European improvements reported that small canals were more economical.⁸⁴ While this may have been true in the European context, small canals would limit the exponential growth of the anthracite coal trade. The 120-ton capacity boats of the Lehigh company would have to be unloaded onto smaller boats at Easton to travel down the Delaware at times of low water, thereby increasing the cost of Lehigh coal and limiting the region's ability to deliver anthracite to markets. As one historian aptly stated, it was as if the Lehigh River were a coal highway leading to a dirt path.⁸⁵

⁸³ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 61-63.

⁸⁴ William Strickland, *Reports on Canals, Railways, Roads, and Other Subjects: Made To "The Pennsylvania Society for the Promotion of Internal Improvement"* (Philadelphia: H.C. Carey & I. Lea, 1826).

⁸⁵ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 50.

The design of the canal was not the only limitation of the Delaware Division Canal. Construction problems plagued the project from the beginning. The state hoped to save money on construction by authorizing only small contracts to several companies. Without expert oversight, much of the work was shoddy and had to be redone. Finally, Pennsylvania and New Jersey fought over the water rights of the Delaware and could not come to an amicable agreement. Pennsylvania had to supply all the water for the canal, which often proved insufficient, especially given the leaky soil along the river banks. By 1830, the canal was declared completed, but in reality it was hardly functional. Embarrassed by its poor performance, the state turned to Josiah White and asked him to direct repairs to the canal. Over the next couple years, he oversaw the work (without salary) and the Delaware Division canal re-opened in October of 1832. The total bill was at least \$1,238,028, nearly double its initial budget of \$686,596.⁸⁶

With the completion of the Lehigh and Delaware Division canals, the built environment of the mid-Atlantic took on a new shape. Combined with the Schuylkill Navigation Company, Delaware & Hudson canal, and other improvements in the region that will be discussed in the next section, the Lehigh Coal & Navigation Company had altered the energy landscape to handle hundreds of thousands and even millions of tons of coal per year cheaply and reliably. For example, White estimated that the annual capacity of the Lehigh Canal was over two and a half million tons of coal.⁸⁷

⁸⁶ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 62.

⁸⁷ As White stated in an 1826 report, "It may with confidence be assumed ... that the only limit to the extent of the business that *could* be carried on, would be the quantity of water in the river at the *driest season*. This has been ascertained to be sufficient, 17 miles above Mauch Chunk, to fill one of the large locks on the Lehigh every seven minutes; and from Mauch Chunk down, the locks can be filled and passed either way in five minutes; but allowing a boat of 150 tons ten minutes to pass a lock each way, equal to three boats or 450 tons per hour, it gives 10,800 tons per day, and 2,700,000 tons per year descending and the same quantity ascending, allowing 250 days navigation." While the canal was ultimately built to

The new energy landscape was quickly put to work. By 1825, consumers were becoming more acquainted with the benefits of anthracite coal and increased their use correspondingly. Consumer demand was encouraged by several factors, such as publication of reports by scientists demonstrating the superior heating qualities of anthracite.⁸⁸ In 1830, it was estimated that Philadelphians spent \$308,400 on coal for heating and New Yorkers over \$320,000, and most of this was anthracite.⁸⁹ New York City was sufficiently dependent on anthracite for its heating needs that a shortage in supply over the winter of 1831-1832 caused widespread alarm and led to donations of money for the poor.⁹⁰ While less than 10,000 tons of anthracite were sold in all markets in 1824, sales increased to 107,815 tons in 1829, 394,986 in 1834, and 782,458 in 1839.⁹¹ This growth was facilitated by the synergistic relationship between supply and price. The more anthracite people used, the cheaper it became. The price of anthracite was reduced from \$8.40 per wholesale ton in Philadelphia in 1820 to \$7.00 in 1825, \$6.50 in 1830 and \$5.50 by 1840.⁹² Lowering prices facilitated the development of a positive feedback loop between demand and supply characteristic of a mineral economy.

The years between 1825 and 1840 also saw the development of anthracite in new markets such as steam engines and steam vessels. The creation of these markets will be

handle 120-ton boats, thereby lowering the capacity by 20%, this still provided the capacity for millions of tons of coal to be delivered each year to markets. Lehigh Coal and Navigation Company, *Report of the Engineers of the Lehigh Coal & Navigation Company, Who Were Appointed, on the Nineteenth Instant, a Committee on the Subject of an Expose of the Property of the Company* (Philadelphia: S. W. Conrad, 1826), 5.

⁸⁸ Marcus Bull, *Experiments to Determine the Comparative Value of the Principal Varieties of Fuel Used in the United States, and Also in Europe and on the Ordinary Apparatus Used for Their Combustion* (Philadelphia: Judah Dobson, 1827).

⁸⁹ "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade," 43.

⁹⁰ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 17.

⁹¹ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, 47.

⁹² Prices are for a 2,240 pound ton of wholesale Schuylkill coal in Philadelphia. R. C. Taylor, *Statistics of Coal* (Philadelphia: J. W. Moore, 1855), 405.

discussed in greater depth in the next chapter, but two points are notable in the meantime. First, each of these markets required boosters to help create them. Scientists, engineers, capitalists, and politicians worked to solve the technical difficulties involved in applying anthracite to new tasks and turn technological possibilities into financially practical industries. The Lehigh Coal & Navigation Company was one of the industry's most important boosters, in particular helping to develop the anthracite iron trade beginning in the late 1830s. Second, once new practices were established, consumption patterns increased dramatically. As people learned to use coal in new ways, they always seemed to want more.

The increased activity of the coal trade drew significant attention to the Lehigh Coal & Navigation Company's activities. In general, this public attention was negative. While few people had cared about the generous privileges given to White and Hazard in 1818, by the early 1830s, these were under attack. In particular, people argued that the right to both mine and ship coal gave the company a virtual monopoly in the development of the Lehigh Valley since its competitors would be dependent on the canal for transport. In contrast to the few operators in the Lehigh Valley, the Schuylkill region was a center of individual enterprise, with hundreds of small businesses. People believed the fact that the Schuylkill Navigation Company was not permitted to mine coal led it to encourage competition, not create a monopoly.⁹³

⁹³ This point was partially true. In addition to the differences between the charters, there were environmental and geographic differences between the regions. The rugged nature of the upper Lehigh Valley meant that fewer settlers were inclined to develop its resources. More importantly, the geography of coal deposits favored individual enterprise in the Schuylkill region. Many of its coal reserves were near the surface, where very little capital was needed to enter the trade. Much of the coal in the Lehigh and Wyoming valleys, with the exception of the Summit Hill mine, required expensive shafts and ventilation systems to be installed. These higher capital costs discouraged small enterprises.

These protests led to investigations of the company's operations by the Pennsylvania government in 1832 and 1834. Through hearings, opinion pieces in newspapers, and circulated pamphlets, people expressed the view that the Lehigh Coal & Navigation Company was a monopoly power. People suggested a variety of remedies for this evil, including rescinding the coal mining privileges of the company, increasing the tolls on the Delaware Canal to punish the Lehigh Coal & Navigation Company, chartering a railroad company with parallel rights of way to introduce competition, and exercising the right of the state to purchase the canal and make it a public highway. Ultimately, the investigations did not lead to any official action taken against the company, and it was able to continue its activities, albeit with much less public support.⁹⁴ The most significant effect on the company was an inability to amend its corporate charter to increase its capitalization, forcing it to carry large amounts of debt.⁹⁵ In 1840, there was another series of allegations made in Philadelphia newspapers attacking the operations of the company, causing Josiah White to write defenses of the company under the pseudonym "Honestas."⁹⁶

The attacks against the Lehigh Coal & Navigation Company are important because they reveal that people were recognizing the importance of coal to the region's future by the 1830s. These protests did not question whether the anthracite trade was a

⁹⁴ See, for instance: *Counter Report of the Minority of the Committee to Whom Was Referred the Memorials of a Number of the Citizens of the Commonwealth of Pennsylvania Praying That the Same Rates of Toll May Be Charged on the Delaware Division of the Pennsylvania Canal as Are Charged by the Lehigh Coal and Navigation Company for the Use of the Lehigh Canal and Praying That Additional Privileges May Be Granted to the Beaver Meadow Rail-Road Company*, (Harrisburg: Henry Welsh, 1832); Josiah White, *To the Committee on Corporations of the Senate* (Harrisburg: Hamilton & Son, printers, 1832); "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade."

⁹⁵ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, 22.

⁹⁶ X, *Exposure of the Lehigh Coal and Navigation Company*, by X (Philadelphia: S.n., 1840); Honestas, "A Defence of the Lehigh Coal and Navigation Company from the Assaults Made Upon Its Interests by X.," (Philadelphia: Jesper Harding, 1840).

good thing. Instead, the key question was how the industry would be operated and who would derive the benefits. Anthracite coal, to many people, was too important to be left to monopoly powers.

By the late 1830s, the continued expansion of anthracite consumption justified further extensions of the Lehigh's transport infrastructure. The company decided to create a canal along the upper section of the Lehigh River between Mauch Chunk and Stoddartsville. Because of the major drop in height over the upper section (600 feet over 26 miles), the company would need to build seventy-five locks over the stretch if they stuck with conventional locks that averaged nine feet. Even though Josiah White had retired from active management of the company in 1831, he was still involved in decision-making. He proposed locks as high as thirty feet tall, which he believed would save a full day's time in transit. The company began interviewing engineers for the job, but none of them thought White's plan was feasible. Eventually, the company hired Edwin Douglas. As White described the hiring process, Douglas' willingness to use his design was the key factor: "On apply[g] to Engineers to carry out this plan, they one & all objected; some one plea, & some another, untill I came to E. A. Douglass, our present Superintendent & Engineer, & he on my nameing the plan to him agreed to it, at once, & at once I employ[d] him."⁹⁷

This section of the canal, known as the Upper Grand Section, was built between 1835 and 1838. Workmen constructed 20 dams, including one as high as 58 feet, as well as 29 locks, some as high as 30 feet. White's design enabled the locks, even as high as

⁹⁷ White, *Josiah White's History, Given by Himself*, 61.

30 feet, to be filled or emptied in less than five minutes. Edwin Douglas stayed on with the company and became its chief engineer until his death in 1860.⁹⁸

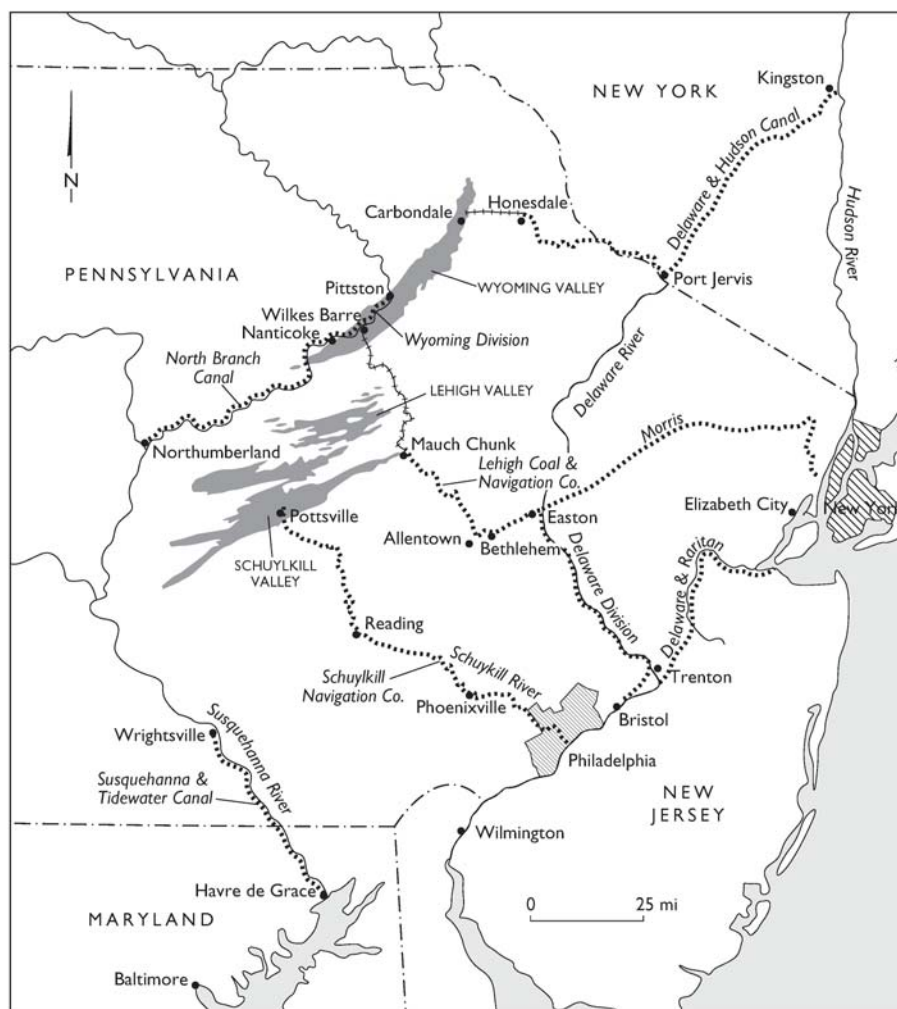
The Lehigh Coal & Navigation Company's developments during this period demonstrate the interconnections between transport infrastructure and the emergence of new energy consumption practices. The early stages of river improvement allowed the company to ship enough coal to begin creating markets. As those markets developed, demand began to drive supply, thereby requiring an expansion of the energy landscape to ensure that markets never lacked for coal. This synergistic pattern of shipping coal, working to create demand, and then expanding infrastructure, was an important part of the development of a mineral economy.

The Anthracite Canal Network

The Lehigh Coal & Navigation Company played a pioneering role in developing the anthracite coal trade. Its early infrastructure developments and marketing efforts laid the critical groundwork for the future development of the trade. However, it was not the only player reshaping the energy landscape of the mid-Atlantic. Several other canals, and later railroads, were built during the antebellum era to bring anthracite to markets. This section reviews the broader anthracite transport network, focusing on the competitive and collaborative dynamics of the system.

⁹⁸ The construction of the Upper Section of the Lehigh Canal is well detailed by Joan Gilbert: Gilbert, *Gateway to the Coalfields: The Upper Grand Section of the Lehigh Canal*.

Map 1.2: The Anthracite Canal Network, 1840s



Two other major canals delivered coal from northeastern Pennsylvania to the eastern seaboard, each connected to one of the main anthracite fields. One was the Schuylkill Navigation Company, which improved the Schuylkill River between Philadelphia and the coal regions above Pottsville. In the beginning, coal did not play an important role in the development of the Schuylkill River. As late as 1818, the company's directors thought 10,000 tons of business per year to be an optimistic estimate.⁹⁹ Instead, the goal was to improve navigation for a general trade whereby

⁹⁹ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 129.

agricultural goods would flow downriver to Philadelphia and manufactured goods would be sent upstream. Much of the financial support for the company came from farmers who lived along its banks and subscribed to a large percentage of its initial capitalization of \$500,000 in 1815.¹⁰⁰

By the time the canal was actually finished in 1825, after ten years of construction and \$2.2 million in expenditures, coal was the main article of trade.¹⁰¹ Despite starting coal shipments five years after the Lehigh Coal & Navigation Company in 1825, more coal was being shipped along the Schuylkill than the Lehigh by 1828 (47,284 versus 30,111 tons). The rate of expansion was dramatic, as the canal shipped 339,508 tons in 1835 and 452,291 in 1840. In conjunction with the Reading Railroad, which began shipping coal in 1841, the Schuylkill region would ship more anthracite to market than any other region up through the Civil War, transporting over three million tons in 1860.¹⁰²

The Delaware & Hudson canal was the second major canal network. Pioneered by the Wurtz brothers of Philadelphia, the Delaware & Hudson canal connected the northern coalfields of the Wyoming Valley with New York City via a 60-mile canal between the Delaware and Hudson rivers. Speculators saw it as a great investment opportunity. When shares in the new company were put on the market on January 8, 1825 in New York City, the whole subscription for \$1.5 million was sold out by 2 in the

¹⁰⁰ The capital structure of the company made shares available to farmers, even if they had moderate incomes. Each share cost \$50 and a person could subscribe with a down payment of only \$5. Ibid., 126.

¹⁰¹ Practically every canal constructed over this time period took more time and money than expected. This makes the accomplishment of White along the Lehigh River that much more impressive.

¹⁰² Shipment data from Jones, *The Economic History of the Anthracite-Tidewater Canals*, 149-54.

afternoon.¹⁰³ Work began on the canal in July of 1825 and the first canal boats crossed it in February of 1829.¹⁰⁴ Once the canal boats reached the Hudson River near Kingston, they could float the remaining distance to New York City.

The Delaware & Hudson Canal was more similar to the improvements on the Lehigh than the Schuylkill. The company's charter gave it the right to mine and ship coal, and the development of the Wyoming Valley, like the Lehigh Valley, was managed by a few large corporations. The company also found itself the target of social critique, particularly over the price of its coal. In its 1823 prospectus, used to get a charter from the New York legislature, the company claimed it could deliver coal at \$3.25 per ton. By 1831, the price was still \$8.00 and people believed the coal was not as high quality as Schuylkill or Lehigh coal.¹⁰⁵ Despite some rocky starts and poor financial results over its first decades, the company also greatly expanded its coal shipments, from 43,000 tons in 1830 to 148,400 in 1840 and 432,339 in 1850.¹⁰⁶

Two canals were built across New Jersey to transport coal from the Lehigh and Schuylkill regions to the New York harbor. The Morris Canal was chartered in 1824. This canal cut across the mountainous northern part of the state, connecting Easton, PA with Jersey City, NJ. Because New Jersey lawmakers believed it would be a profitable investment, both by bringing Lehigh coal to New York City and stimulating the development of trade in the mineral-rich district through which it would pass, the state chose to develop the canal itself. As with the Delaware & Hudson canal, the shares were

¹⁰³ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 36.

¹⁰⁴ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 76-78.

¹⁰⁵ *Ibid.*, 81.

¹⁰⁶ *Ibid.*, 86.

sold immediately in a speculative craze in 1825. However, construction did not go smoothly. The state company installed inclined planes to ascend the nearly fifteen hundred feet of elevation gain between Easton and the western end of the canal, but they never worked as well as hoped. Moreover, the small size of the canal meant only 25-ton canal boats could travel along it, restricting the amount of coal traffic traveling between the Lehigh Valley and New York. The canal was opened in 1831 as far as Newark and was eventually completed to the New York harbor. It succeeded in stimulating the development of the regions along its path, but it never achieved the financial success that encouraged its initial development.¹⁰⁷

The Delaware & Raritan canal, by contrast, was far more successful, financially and as a coal carrier. Begun in 1830 and completed in 1834, the canal allowed coal boats to travel from Trenton, NJ, along the Delaware River, to New Brunswick, where the Raritan River led to the New York harbor. Canvass White, who also worked on the Lehigh Canal, led construction efforts and designed the canal to handle large boats. This made it easy for coal shipped from the Lehigh or Schuylkill rivers to be sent directly to New York without unloading at Philadelphia, drawing much of the traffic away from the Morris Canal. In addition, the flatter terrain of the middle of New Jersey made canal development much easier. By 1860, more than a million tons of coal were being shipped along this route.¹⁰⁸

Finally, improvements along the Susquehanna River as part of the State of Pennsylvania canal network connected the anthracite regions with Harrisburg and

¹⁰⁷ Ibid., 109-12.

¹⁰⁸ Ronald E. Shaw, *Canals for a Nation: The Canal Era in the United States, 1790-1860* (Lexington, Ky.: University Press of Kentucky, 1990), 94-97.

Baltimore. The North Branch was completed between Northumberland and the Nanticoke Dam, 55 miles upriver in 1830. The Wyoming Division ran for seventeen miles above this point, allowing the coal trade to descend along the Susquehanna beginning in 1834. Many hoped the state would build an extension of the North Branch connecting the Wyoming Valley to the Erie Canal system thereby introducing anthracite to more of New York State. Despite several attempts to build such a canal, construction challenges delayed its completion until 1853. Overall, the total amounts of coal traveling along the Susquehanna River were minor in comparison with shipments along the Lehigh, Schuylkill, and Hudson rivers, although as much as five hundred thousand tons were carried in 1855.¹⁰⁹

The millions of dollars spent on infrastructure to move coal attest to the critical nature transportation played in the development of a fossil-fuel intensive society. Anthracite was the major item of trade on all these canals, meaning that their economic success was tied to the fate of the coal trade. Just as important, the coal trade owed its success to the activities of the transporting companies. From an economic perspective, the investments in the transportation of coal far outweighed the costs of mining it. For example, by 1834, over \$9,750,000 was invested in transport infrastructure (canals and railroads) in the anthracite regions while only \$1,270,280 was invested in collieries (and much of this capital was spent on boats and wagons).¹¹⁰ Mining coal was physically demanding labor, but there were few barriers to extracting it from the ground, particularly in the early years before extensive underground mines were established. Getting coal to

¹⁰⁹ Ibid., 80-82.

¹¹⁰ "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade," 31.

market was much harder and more expensive.¹¹¹ As Thomas Dublin and Walter Licht note: “[t]he movers and shakers of the trade would be the transporters and merchandisers of coal, not the operators of mines.”¹¹²

While the routes of the canals did not change once they were established, they were not static technologies. In addition to regular maintenance, the canals were steadily expanded in order to handle the increased demand for coal. For example, the Schuylkill canal was widened and deepened in 1840 and 1846, allowing 180-ton boats to pass. The Delaware & Hudson canal was enhanced in 1842, 1845, 1850, and 1853 to allow boats to increase their loads from 30 tons to 140 tons of coal.¹¹³ These expansions were crucial to making sure that transport of fossil fuels would not limit consumer demand. Widening canals was a key factor in establishing a built environment conducive to the positive feedback loops of the mineral economy.

The canal companies were competitors of one another, seeking to establish the primacy of their coal in the market and control the market.¹¹⁴ However, in many ways, their competitive nature was less important than the synergies between them. Each of the companies worked to build demand for coal, thereby creating a larger base of consumers. By providing multiple sources of supply, they generated a more reliable market, making customers feel more secure in switching to anthracite. Even their competitive actions had the general effect of increasing the market. By lowering the cost of coal in rate wars or increasing production to gain market share, the companies gave consumers further

¹¹¹ The difficulty of transporting anthracite coal can be contrasted with the British example. Although the development of canals and other waterway improvements facilitated the British coal trade, much of the coal was located near waterways, making it easier for this trade to be initiated.

¹¹² Thomas Dublin and Walter Licht, *The Face of Decline: The Pennsylvania Anthracite Region in the Twentieth Century* (Ithaca, N.Y.: Cornell University Press, 2005), 12.

¹¹³ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 82-83, 131, 138.

¹¹⁴ In the antebellum period, anthracite was often sold according to its region of origin.

incentives to use anthracite because it was constantly becoming cheaper and more plentiful. Ultimately, the synergistic growth of the canal companies, not their competitive nature, was more important to the development of an energy landscape of fossil fuel abundance.

Increased Consumption, Iron, and Railroads, 1840-1860

By 1840, consumer demand for anthracite coal had been firmly established. Over the next two decades leading up to the Civil War, three trends were particularly important in shaping the activities of the Lehigh Coal & Navigation Company and other coal transporters: continued expansion of demand for anthracite, the development of an anthracite iron industry, and the emergence of railroad competition.

Anthracite use continued to expand between 1840 and 1860 by a factor of 10 (see Table 1.1). The largest market remained home heating, although substantial amounts of anthracite were used in steam vessels, steam engines, and iron manufacture (as discussed in this section and the next chapter). Moreover, these totals do not include the amounts of anthracite consumed in the process of coal mining. The huge steam engines used to pump water and coal to the surface from underground mines consumed additional quantities of hundreds of thousands of tons. These steady increases of demand encouraged the continual expansion of the energy landscape to supply the market.

Table 1.1: Anthracite Coal Shipments, By Region, in Tons, 1820-1860¹¹⁵

Year	Schuylkill	Lehigh	Wyoming	Total	% Increase
1820		365		365	
1825	6,500	28,393		34,893	9459%
1830	186,059	41,750	43,000	270,809	676%
1835	339,508	131,250	90,090	560,848	107%
1840	452,291	225,318	148,470	826,079	47%
1845	1,083,796	429,453	451,836	1,965,085	138%
1850	1,712,007	690,456	827,823	3,230,286	64%
1855	3,318,555	1,284,113	1,771,511	6,374,179	97%
1860	3,270,516	1,821,674	2,941,817	8,034,007	26%

The second major development during this period was the creation of an anthracite iron industry. In the 1830s, American iron production was lagging behind foreign competitors, in both output and quality. Britain produced far more iron than America and iron from Sweden was known for having the highest quality. Many Americans were concerned by this state of affairs and thought the nation's economic future would be strengthened by a robust iron industry. Discovering how to use anthracite for smelting was one way many people thought this process could be improved. However, the emergence of an anthracite iron industry was not inevitable. It was actively shaped by the region's boosters. For example, the Franklin Institute of Philadelphia offered a prize for anyone that developed a method for smelting iron with anthracite in 1835. A few months later, Nicholas Biddle (president of the Second Bank of the United States) and a few friends added a \$5,000 cash award to sweeten the pot.¹¹⁶ In 1836, the Pennsylvania legislature granted corporate privileges to any company making iron with anthracite coal.¹¹⁷

¹¹⁵ Miners' Journal, *Coal Statistical Register for 1870*, Insert "Anthracite Coal Trade of the United States".

¹¹⁶ Thomas Childs Cochran, *Frontiers of Change: Early Industrialism in America* (New York: Oxford University Press, 1981), 93.

¹¹⁷ Craig L. Bartholomew, Lance E. Metz, and Ann M. Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley* (Easton, Pa.: Center for Canal History and Technology, 1988), 11.

The Lehigh Coal & Navigation Company was also interested in developing an iron market and pursued several activities to make this happen. First, it offered inducements to entrepreneurs as early as 1834, such as free water power, lower rates on coal, and cheap transport of finished goods to anyone who could produce iron with anthracite. By 1838, one small factory was located in Mauch Chunk, but its production was limited to a ton and a half a day.¹¹⁸ Second, the company sent representatives to Wales where several ironmasters had experience working with anthracite coal. Solomon Roberts, the nephew of Josiah White, traveled in 1837 to Wales and met David Thomas, the superintendent at George Crane's iron factory to learn the process. The next year Erskine Hazard followed Roberts. The men formed an agreement with George Crane and returned with David Thomas to the Lehigh Valley in 1839 to set up a factory.¹¹⁹

David Thomas scouted the Lehigh Valley and decided to establish his factory at Catasqua (about three miles upriver of Allentown). The Lehigh Crane Iron Company was established on May 20, 1839 and produced its first anthracite iron on July 3, 1840. The company became highly successful and contributed to a revolution in American iron production. In 1840, there were 6 forges in America making pig iron using anthracite. By 1846, there were 42, all of them located in Pennsylvania and New Jersey. A decade later, 121 furnaces were forging iron with anthracite and 93 of them were in Pennsylvania. American pig iron production had increased from 220,000 tons in 1842 to 750,000 tons in 1847. Anthracite not only helped the iron industry increase its production, but the quality of the iron was also generally higher because the coal did not

¹¹⁸ Richardson, *Memoir of Josiah White. Showing His Connection with the Introduction and Use of Anthracite Coal and Iron, and the Construction of Some of the Canals and Railroads of Pennsylvania, Etc.*, 100-01.

¹¹⁹ *Ibid.*, 102.

have sulfur and the price was cheaper—\$12 per ton compared to \$16 per ton for iron made with charcoal.¹²⁰

There were numerous social consequences of this transformation in iron production. First, it generated a geographical change in the location of forges. Previously forges were built in forested areas where there was enough wood to generate charcoal. With the adoption of anthracite, furnaces could be clustered along transport networks such as canals. Moreover, Northeast Pennsylvania became the undisputed center of American iron production, and the Lehigh Valley took center stage: “By 1856, 19 percent of the iron furnaces in the United States and 21.5 percent of the furnaces of Pennsylvania were in the Lehigh Valley.”¹²¹ Connected to this change in location, iron became much cheaper because both production and transport costs declined. A ton of iron could be shipped to Philadelphia or New York for about a dollar a ton, versus five to eight dollars from country forges.¹²² Third, the increased iron production bolstered American industry. Cheap and abundant iron made the rapid expansion of railroads, steam engines, and machinery feasible during this period. And, of course, it required burning lots of coal, thereby furthering the development of a fossil-fuel intensive society.

The third major development in these years was the rise of railroad competition for the transport of anthracite. In many ways, the Lehigh Coal & Navigation Company was spared the worst effects of railroad competition during the antebellum era. Whereas a bitter thirty-year war emerged between the Schuylkill Navigation Company and

¹²⁰ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 64.

¹²¹ Charles Waltman, "The Influence of the Lehigh Canal on the Industrial and Urban Development of the Lehigh Valley," *Proceedings of the Canal History and Technology Symposium* (1983): 88.

¹²² Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 64.

Reading Railroad beginning in 1842, serious railroad competition did not emerge in the Lehigh Valley until the mid-1850s. In addition, as evidenced by the construction of its gravity railroad in 1827, the White and Hazard's company saw railroads as complementary to canals, not necessarily exclusively as competitors. From 1830 to 1833, the company constructed another railroad connecting its mines at Room Run (four miles from the Lehigh River) to Mauch Chunk. And beginning in 1837, the company began construction on a canal that would connect White Haven (15 miles north of Mauch Chunk) with Wilkes-Barre, thereby forming trade links with the Wyoming Valley.¹²³

The company's railroad developments took both a step forward and backward in the winter of 1841 when a devastating flood wrecked much of the canal. Blocks of ice rushed over dams and destroyed locks the whole length of the Lehigh River. Even though they were likely unaware of it at the time, this was not simply an act of God. The company's heavy cutting of timber from the upper section of the river decreased the ability of the soil to hold water, funneling more into the river. In addition, the newly constructed dams served to keep much more water in the river so that when they burst, the floodwaters were more destructive.¹²⁴ Company engineers estimated that repairing the damage cost several hundred thousand dollars. Josiah White came out of retirement and re-invested much of his fortune to keep the company in business. By the next year, the section between Mauch Chunk and Easton was repaired although it took until 1843 for the upper grand section to be fixed.¹²⁵ The flood had the unintended consequence of

¹²³ *History of the Lehigh Coal and Navigation Company, Published by Order of the Board of Managers*, 23-24.

¹²⁴ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 51.

¹²⁵ Hansell, *Josiah White: Quaker Entrepreneur*, 122-23.

weakening public attitudes against the company, and the legislature aided the company by allowing it to expand its capitalization to six million dollars thereby putting it on more secure financial footing.¹²⁶

The flood delayed the completion of the company's railroad projects. The railroad to Wilkes-Barre, despite being nearly finished in 1840, was not opened until 1846. In addition, the company had plans to replace the gravity railroad with a switch back railroad. This was finally executed in the mid-1840s. The company set up two inclined planes that allowed the carts to be pulled up at only two locations, and then coast on gravity for the rest of the journey. This successful design saved money and eliminated the need for mules and horses to drag the carts between the mine and the river. Like the gravity railroad, it proved to be a major tourist attraction.¹²⁷

The company also faced the competitive threat of rival railroads. As early as 1830, the Pennsylvania legislature had given a charter for a railroad company to open a line parallel to the canal. It was hoped this would break the canal's monopoly. The Beaver Meadow Railroad was completed in 1836, and began delivering coal from the Lehigh Valley to Easton. The Lehigh Coal & Navigation Company did not take kindly to its new competitor, and in the proper spirit of capitalists at the time, the fighting was occasionally ugly. The Lehigh company had a habit of stationing its lumber workers on the slopes above the Beaver Meadow employees, with the result that several trees would come barreling through the railroad workers.¹²⁸ Both sides were said to have armed their

¹²⁶ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 25.

¹²⁷ Shank, *The Amazing Pennsylvania Canals*, 67-69.

¹²⁸ Ann M. Bartholomew and Lance E. Metz, *Delaware and Lehigh Canals* (Easton, Pa.: Center for Canal History and Technology, 1989), 142.

men with muskets.¹²⁹ However, the Beaver Meadow Railroad never emerged as a major competitor. Because it did not have links all the way to the eastern seaboard, it delivered most of its coal to points along the canal to be sent to market.¹³⁰

The Lehigh Valley Railroad emerged as a much stronger foe in the 1850s. Philadelphia capitalists organized this company in 1846, but could not get adequate funding, partially because the Lehigh Coal & Navigation Company actively campaigned against the company's prospects. Asa Packer, a successful manufacturer of canal boats and coal producer, took control of the dormant company in 1851. Despite a litany of challenges involved in raising the necessary money, he persisted and the railroad was completed between Mauch Chunk and Easton in 1855. From Easton, Packer could ship coal south to Philadelphia over the Delaware Division canal, or east to New York via the New Jersey Central Railroad or the Morris and Delaware & Raritan canals. The railroad soon took much of the coal traffic from the canal, increasing its coal shipments from 9,063 tons in 1855 to 730,642 in 1860, 1,502,277 in 1865 and 3,608,587 in 1870 (versus 888,784 in 1865 for the canal and 789,112 in 1870).¹³¹

By 1860, railroads began overtaking canals as the primary shippers of anthracite coal. The dominance of the Schuylkill, Lehigh, and Delaware & Hudson canals was soon replaced by the Reading, Lehigh Valley, and Delaware, Lackawanna, and Western Railroads, respectively. Railroads had a few advantages that helped them achieve a competitive edge. First, they could be operated year-round, whereas canals were frozen for some of the winter and occasionally had limited traffic during the dry months of

¹²⁹ Hudson Coal Company, *The Story of Anthracite* (New York: 1932), 99.

¹³⁰ Brzyski, "The Lehigh Canal and Its Economic Impact on the Region through Which It Passed, 1818-1873", 594.

¹³¹ Miners' Journal, *Coal Statistical Register for 1870*, Insert "Anthracite Coal Trade of the United States".

summer. Second, railroads had greater physical capacities. Had the Lehigh Canal been built to handle 150-ton capacity boats as White originally hoped, he estimated that its capacity would be 2,700,000 tons of coal a year. By 1862, the Reading Railroad's coal shipments had already exceeded this number, and the Lehigh Valley Railroad was shipping more than three million tons by 1870.¹³² Third, railroads had greater geographic flexibility. There were limitations on where canals could be placed based on water supply and elevation. Railroads could travel across landscapes not conducive to canal development.

However, the transition to railroads did not have the same revolutionary effects as the development of the canal network. The canal network created a new energy landscape in the mid-Atlantic, making it possible for the first time to deliver fossil fuel energy to the eastern seaboard in large quantities. Railroads altered and extended this energy landscape, but did not revolutionize it. Most importantly, the flows of coal along railroads were similar to the flows along canals. The large majority of the coal shipped on railroads from Northeastern Pennsylvania went to Philadelphia and New York just as it had with canals. Railroads had greater capacities and funneled their profits to different people, but these were differences in degree, not in kind. The energy landscape of railroads was very similar to the energy landscape of the anthracite canal network.

Conclusion

The history of the Lehigh Coal & Navigation Company is filled with impressive technological achievements. Josiah White and Erskine Hazard were innovative geniuses

¹³² Ibid.

who favored the practical over the theoretical. Even before they turned their attention to the Lehigh River, the men proved their acumen by damming the Schuylkill River, developing new techniques for manufacturing wire, inventing iron canal boats, and building the first wire suspension bridge in America. On the Lehigh River, they pioneered the development of bear trap locks, a gravity railroad, double-wide locks on the lower grand section, thirty-foot high locks on the upper grand section, and the switch-back railroad.

In the post Civil War era, the company would continue to operate for several decades, although by the 1870s, it would be in a state of steady decline. When a disastrous flood in 1862 destroyed much of the canal, the company turned its attention to developing railroads for coal delivery. While the canal would continue to be operated into the twentieth century, the coal traffic steadily declined. As late as 1906, the company experimented with using electric traction to pull canal boats and shipped over 240,000 tons of coal by water that year.¹³³ Various parts of the company continued to exist until 1969, when its last assets were sold.¹³⁴

Impressive as they are, the company's long history and technological achievements are not its most important legacy. Viewed in historical hindsight, the pioneering work of the Lehigh Coal & Navigation Company in creating a new energy landscape in the mid-Atlantic mattered far more. In competition and collaboration with other anthracite canals, the Lehigh Coal & Navigation Company played a crucial role in transforming the energy possibilities for mid-Atlantic residents. In the next chapter, I

¹³³ Jones, *The Economic History of the Anthracite-Tidewater Canals*, 51.

¹³⁴ W. Julian Parton, *The Death of a Great Company: Reflections on the Decline and Fall of the Lehigh Coal and Navigation Company* (Easton, Pa.: Center for Canal History and Technology, 1986).

explore how consumers chose to adopt these new possibilities and how these choices initiated a transition into a mineral economy.

Chapter 2: Coal Flows and Consumption: Creating a Mineral Economy in the Mid-Atlantic, 1820-1860

Residents of the mid-Atlantic region took their first steps into a mineral economy between 1820 and 1860. A quick comparison of domestic and industrial conditions in 1820 and 1860 shows how significant these changes were. In 1820, people warmed their houses with wood burning fires. The limited energy endowments of cities presented finite limits to the number of industrial operations that could be concentrated in a single space. Travel depended on organic sources of energy like animals, wind, currents, and human legs. Most people worked on farms or in commercial trades. By 1860, cities like Philadelphia and New York had grown much larger and their residents kept themselves warm and cooked with anthracite coal. Factories had begun to concentrate in urban locations and use anthracite coal to supplement water and muscle power. Railroads and steam vessels were starting to transport people and goods throughout the region more quickly and regularly than was possible with organic energy sources. While agriculture and commerce remained vibrant, urban industrial enterprises had become the most dynamic and rapidly growing sector of the economy.

The effects of anthracite coal and the creation of a mineral economy were most pronounced in the mid-Atlantic. Philadelphia and New York City had the nation's highest levels of urban and industrial growth. Most of the nation's anthracite coal was burned in the mid-Atlantic's homes, iron furnaces, steam engines, and factories. However, the impacts of these changes were felt beyond the region as well. The consumption of coal in the mid-Atlantic increased economic and political differences

between North and South, contributing to the tensions that precipitated the Civil War.

The proliferation of urban industries in the mid-Atlantic altered flows of immigrant laborers from Europe. The spread of large corporations involved in the mining, transport, and consumption of anthracite influenced debates over the meaning and value of republican ideals for the nation's future. In other words, coal's political, economic, and environmental ramifications often traveled further than the mineral itself.

The development of the mid-Atlantic's mineral economy relied on the smooth operations of the region's energy landscape described in the previous chapter. This canal network structured social energy choices but did not determine the outcomes. In this chapter, I analyze the impacts of this energy landscape by asking the following questions: what were the patterns of coal flows along the conduits of the energy landscape? How did new energy consumption patterns contribute to a shift from an organic to a mineral economy? Finally, how did the development of a mineral economy favor certain groups over others, lead to a society dependent on fossil fuel energy, and affect the development of the region and nation?

Putting the Energy Landscape to Work

Once the construction of anthracite canals created a new energy landscape in the mid-Atlantic, what were the patterns of coal flows along these networks? In brief, the majority of coal was shipped to Philadelphia and New York, the termini of the canals. Urban residents consumed large amounts of this coal and significant quantities were shipped to other cities along the eastern seaboard. At first, comparatively little coal was used in the anthracite region. By mid-century, however, powerful steam engines used to

pump coal and water to the surface of mines consumed large quantities of coal.¹ Little coal was delivered to points along the paths of the canals before the development of an anthracite iron industry in the 1840s and 1850s. Large swaths of the mid-Atlantic were excluded from the new energy landscape, particularly if they were located more than a few miles from the banks of an anthracite canal or navigable river.

Canals did not determine coal flows, but they heavily structured these patterns. The concentration of coal deliveries to Philadelphia and New York was not accidental. Canal boosters designed their systems to reach these cities because these were seen as the most promising markets. Moreover, Philadelphia and New York already had synergistic relationships with the Delaware, Schuylkill and Hudson rivers before these routes were transformed into anthracite highways. These cities were located where they were largely because the rivers offered the potential for cheap transport of goods from the surrounding hinterlands. Philadelphia and New York had developed as large cities with promising markets, therefore, in large part because they were served by rivers. Since canals were most easily built by augmenting existing waterways, it is hardly surprising that Philadelphia and New York became the primary outlets for an energy landscape based on water transport.

The design of canals also shaped the flows of coal to other parts of the region. Very little coal was delivered to areas more than a few miles away from the canals because the overland transport of coal remained prohibitively expensive for most purposes. Most of the land area in the mid-Atlantic, therefore, was not integrated into the new energy landscape. The construction of the canal network also had less obvious

¹ Because this coal did not “flow” (it was used directly at the site of production) I will discuss these consumption patterns in detail in the next section of this chapter.

impacts on coal flows. The fact that canals could deliver goods in two directions was critical for the development of an anthracite iron industry along their banks. At sites like Reading and Phoenixville along the Schuylkill canal and Bethlehem and Allentown on the Lehigh canal, entrepreneurs erected large iron works soon after they solved the technical problems of forging iron with anthracite. Canals could deliver coal from mines above the forges *and* inputs such as lime and ore from both upstream and downstream sites. The canals then provided cheap transport to markets for the finished goods. Finally, canals often supplied water power that could be used to operate blast furnaces.² Therefore, the design of the canal network facilitated the emergence of a new geography of iron production along the banks of the river.

This section illustrates these patterns by closely analyzing the flows of coal along the Lehigh and Schuylkill canals. Here and in the rest of the chapter, I draw heavily on statistics. I have spent significant time collecting these statistics from a wide variety of sources including government reports, trade journals, and industry analyses.³ To my knowledge, the data in this chapter is the most complete set of information on anthracite flows and consumption in the mid-Atlantic gathered to date. It represents a significant contribution to our knowledge of how, when, and where coal was used during this period.

However, this evidence must be read carefully. The antebellum era has been aptly described as “the statistical dark age” because the available data are neither

² The water power was derived from funneling water out of the main channel through sluice gates that powered water wheels or turbines.

³ Different sources often have competing data. I have done my best to present what I consider to be the most useful data by triangulating between various sources and assessing the reliability of historical documents.

abundant nor reliable.⁴ For example, coal weights were not always standardized. Tons were alternatively measured as 2,000 or 2,240 pounds and the contents of a bushel often varied from time to time and place to place. As a result, this data is most usefully read for trends rather than specific facts about a given year. In other words, we have no way to verify whether exactly 429,492 tons of coal were shipped on the Lehigh canal in 1840. However, we can feel confident that the shipments in that year were roughly double the company's operations five years before and would nearly double again by 1845.

Coal along the Lehigh

The anthracite coal trade began in earnest on the Lehigh Canal in 1820. Over the next forty years, coal from the Lehigh region was sent along three main routes. First, the Lehigh Coal & Navigation Company delivered anthracite to Philadelphia. Second, coal was shipped to the New York harbor via the New Jersey canals starting in the 1830s. Finally, the iron forges along the path of the Lehigh Canal consumed large quantities of coal beginning in the 1840s.

Philadelphia was the initial destination for anthracite coal from the Lehigh Valley. For the first decade of its operations, the Lehigh Coal & Navigation Company sent all of its coal to Philadelphia, where about half was consumed. The balance was shipped to other cities on the eastern seaboard including New York, Boston, and Providence (see Tables 2.1 and 2.5). Philadelphia did not remain the major transshipment point for the Lehigh Coal & Navigation Company for long, however. When the Delaware Division canal was completed in the early 1830s, the company established coal wharves at Bristol,

⁴ Diane Lindstrom, *Economic Development in the Philadelphia Region, 1810-1850* (New York: Columbia University Press, 1978), 2.

the southern terminus of the canal about twenty miles north of Philadelphia. At Bristol and points south, the water depth of the Delaware River was sufficient to allow steam vessels to pull coal boats all the way to the Atlantic seaboard. From this point in time, the company sent coal to its Philadelphia wharves for local consumption and managed its exports from Bristol. Throughout the antebellum period, Philadelphia remained an important and growing market for the Lehigh Valley coal trade, although its relative receipt of coal shipments declined over time.

When the Morris and Delaware & Raritan canals opened in the early 1830s, the Lehigh Coal & Navigation Company began to divert many of its coal shipments towards the New York harbor. The large majority of the coal shipped on the Delaware & Raritan canal reached the coal wharves at Elizabeth. By contrast, significant quantities of coal were consumed along the path of the Morris Canal due to its concentration of iron and mineral industries. The flow of Lehigh coal to New York along the New Jersey canals steadily increased in quantity and importance. In 1835, less than 25 percent of the coal shipments went to New York. By 1860, more than 50 percent of coal shipments traveled this route (see Table 2.1). This change both reflected and shaped the decline of Philadelphia as the primary port for anthracite and the corresponding rise of the New York harbor.⁵

The rise of New York's port was partly a result of trade advantages and partly the construction of transport infrastructure. At the beginning of the nineteenth century, New York City surpassed Philadelphia as the nation's main port through a combination of

⁵ Up through the 1840s, Philadelphia's port had been the primary coal market but New York had overtaken it by the 1850s. For information on Philadelphia's coal exports, see *Ibid.*, 58. On the rise of New York as the primary coal market, see *Pennsylvania Coal and Its Carriers*, (Philadelphia: Crissy & Markley, Printers, 1852), 23.

geography, port improvements, public policy, and the synergistic concentration of finance and markets in a single location.⁶ New York also benefited greatly from the opening of the New Jersey canals, which connected the Lehigh and Schuylkill regions with the New York harbor. Philadelphians were aware of the threat to their port from the Morris and Delaware & Raritan canals and tried to maintain control of the trade. For example, the Delaware & Raritan canal began on the Delaware River near Trenton, north of Bristol. For many years, the Pennsylvania legislature refused to create an outlet lock on the Delaware Division canal that would allow coal boats to transfer directly to the Delaware & Raritan. Instead, the boats had to travel all the way south to Bristol and then be pulled up the other side of the Delaware River to the entrance of the Delaware & Raritan. Only in 1848, nearly fifteen years after the completion of the Delaware & Raritan canal, did the state legislature create an outlet lock.⁷ The battle over the outlet lock shows the ways in which transport infrastructure was used as a competitive weapon in intra-regional struggles.

Third, some coal was consumed along the path of the canal. Before 1840, this was a minor part of the trade. In 1839, businesses and residents along the path of the canal consumed as little as 6 percent of total shipments—13,733 out of a total of 221,850 (Table 2.1). The development of the anthracite iron industry in 1840 created new patterns of consumption. Led by the Lehigh Crane Iron Company and supported by the Lehigh Coal & Navigation Company, the Lehigh Valley quickly became the nation's

⁶ The classic work on this topic is Robert Greenhalgh Albion, *The Rise of New York Port, 1815-1860* (Hamden, Conn.: Archon Books, 1961).

⁷ Despite the connections of White and Hazard to Philadelphia, they made several petitions to the state of Pennsylvania to construct an outlet lock at Black's Eddy which would allow them to send coal directly to New York. The state largely ignored their request, eventually building the outlet lock at New Hope and charging coal boats an additional fee to use this outlet lock. *A Review of the Question of the Outlet Lock at Black's Eddy*, (Philadelphia [?]: s.n., 1840).

leading site of iron production. Entrepreneurs established several additional iron forges along the canal in towns such as Allentown and Bethlehem. As the industry matured, these enterprises along the path of the canal began consuming nearly 20 percent of the company's overall shipments. By 1854, the local consumption had grown in fifteen years from 13,733 to 243,825 tons.⁸

Railroad competition did not alter the dynamics of coal flows in the Lehigh Valley dramatically during the antebellum era. The Beaver Meadow Railroad began to ship coal in the 1830s to Easton, which was then transshipped to eastern seaboard markets along the Delaware Division and New Jersey canals. The Lehigh Valley Railroad was completed in 1855 and quickly became a major competitor of the Lehigh Canal, acquiring 730,642 tons of the coal trade by 1860. While this railroad took over much of the coal trade of the Lehigh Valley, the geography of its coal deliveries were similar to the canal shipments.⁹

⁸ Tonnage data from Lehigh Coal and Navigation Company, *Report of the Board of Managers of the Lehigh Coal and Navigation Company, Presented to the Stockholders* (Philadelphia: various printers, 1828-1859).

⁹ See previous chapter for more information on the Beaver Meadow and Lehigh Valley Railroads, including shipment data.

Table 2.1: Coal Flows from the Lehigh Region, in Tons, 1820-1860¹⁰

Year	LC&NC shipments	Consumed along line	To Morris	To Delaware Division	To Delaware & Raritan	To Philadelphia	Shipped from Philadelphia / Bristol
1820	365						
1825	28,393					11,245	11,378
1830	43,000	7,615				12,601	20,391
1835	131,250		40,000				70,194
1840	225,585	23,955	30,210	171,210			
1845	429,492	(81,726)	12,567	335,199	30,985		
1850	723,099	117,119	98,100	507,323			
1855	1,276,367	229,056	290,730	755,265	156,340		
1860	1,091,032	(174,462)	276,947	639,623	341,816		

Coal Flows from the Schuylkill Region

Although coal from the Lehigh region initiated the anthracite trade, the Schuylkill region soon surpassed its rival to become the largest producer and shipper of coal during the antebellum era. The coal flows from this region went through two major phases. The first, between 1825 and 1840, was characterized by large flows of coal along the Schuylkill canal directed towards Philadelphia and shipped to the eastern seaboard. In the second phase, from 1840 to 1860, the Reading Railroad overtook the canal as the major transport company, the anthracite iron industry began to consume large quantities of coal, and some coal began to flow directly to New York. With the exception of the early introduction of railroad competition, the flow of coal from the Schuylkill region shared many of the patterns of the Lehigh region.

¹⁰ Numbers in parentheses are estimates made by subtracting shipments on the Morris and Delaware Division canals from the total shipments. Sources for Table 2.1: Lehigh Coal and Navigation Company, *Report of the Board of Managers of the Lehigh Coal and Navigation Company, Presented to the Stockholders*; Jones, *The Economic History of the Anthracite-Tidewater Canals*; Taylor, *Statistics of Coal*, 404; "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade."

Schuylkill Flows, 1825-1840

The first phase of coal flows from the Schuylkill region began in earnest with the completion of the canal built by the Schuylkill Navigation Company in 1825. Small amounts of coal had been sent to Philadelphia when heavy rains raised the waters of the Schuylkill before the canal was complete, but the amounts were negligible and rarely recorded. When the Schuylkill Canal began operations in 1825, Lehigh coal had a five-year head start in the market. However, the Schuylkill Navigation Company quickly closed the gap. In 1825, the Lehigh Coal & Navigation Company shipped more than four times as much coal as the Schuylkill Navigation Company. Only five years later, the Schuylkill region had gained the advantage and sent twice as much coal to market. This discrepancy increased over time as Schuylkill coal shipments began to dwarf those from the Lehigh.

Law and geography were the main reasons the output of the Schuylkill region exceeded other areas during the antebellum era. The Schuylkill Navigation Company was the only transport company whose corporate charter prevented it from mining coal. The Lehigh Coal & Navigation Company and Delaware & Hudson Company, by contrast, had corporate charters that allowed them to both own coal lands and ship coal to market, thereby encouraging these companies to control much of the mining in their regions.¹¹ By contrast, the Schuylkill Navigation Company encouraged the expansion of mining in the region in order to increase its transport revenues, its primary source of income. Geography gave a further advantage to individual enterprises in the Schuylkill

¹¹ While there were independent coal mining companies in the Lehigh and Wyoming valleys, these companies were at a price disadvantage because the Lehigh Coal & Navigation Company and Delaware & Hudson companies could ship their own coal at discounted rates, thereby increasing their profit margins and undercutting competitors.

region. The coal deposits were nearer to the surface than in other regions. This made it easier for small operators to enter the industry because they did not have to invest large quantities of capital to sink deep mine shafts.¹² The proliferation of mining enterprises in the Schuylkill region, therefore, led to exponential increases in output throughout the antebellum era.

The Schuylkill Navigation Company shipped most of its coal to Philadelphia between 1825 and 1840, where about half to two-thirds was transshipped to other cities on the eastern seaboard. As was the case in the Lehigh region, towns along the path of the canal accounted for a small percentage of the coal shipments, about 5-10 percent. Because most of these towns had small populations, it is unlikely that they were experiencing any shortages of firewood for home heating. Therefore, most of this coal was likely used in industrial enterprises, particularly at sites such as Reading, Phoenixville, and Manayunk.

¹² A person could enter the mining industry in 1834 with \$10,000 (\$3,500 for coal land, \$3,000 for opening the land, wagons, \$2,500 for boats, and \$1,000 for working capital) according to an industry analysis. While this was a considerable amount of money at the time, it was not prohibitive. Moreover, these costs overstated the barriers to entry. With tools as simple as picks, shovels, and wagons, an individual could agree to mine coal and pay the property owner a percentage of the profits. "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade," 45.

Table 2.2: Schuylkill Coal Flows, in Tons, 1825-1840¹³

Year	Canal shipments	Consumed along line	Sent to Philadelphia	Direct to New York City	Shipped from Philadelphia	% Increase in shipments
1825	6,500					
1826	16,767				11,596	158
1827	31,360				20,804	87
1828	47,284	3,154			23,039	51
1829	79,973	3,332			36,246	69
1830	89,984	5,321			42,746	13
1831	81,854	6,150			41,546	-10
1832	209,271	10,048			124,690	150
1833	252,971	13,429			154,006	21
1834	226,692	19,429			156,154	-10
1835	339,508	18,571			267,139	50
1836	432,045	17,863	61,944		344,812	27
1837	523,152	21,749	71,916		328,304	21
1838	433,875	28,775	98,707		278,268	-17
1839	442,608	30,990	100,694	27,000	286,990	2
1840	452,291	28,924	90,000	64,388	244,680	2

Schuylkill Flows, 1840-1860

Three developments altered the coal flows from the Schuylkill region beginning around 1840. First, the Reading Railroad, which began operations in 1842, acquired most of the coal trade from the canal. As in the Lehigh region, the development of the anthracite iron industry created a large demand for coal along the paths of the canal and railroad. Finally, much of the remaining coal that was shipped along the Schuylkill canal was sent directly to the New York harbor.

When the Reading Railroad completed its tracks between the Schuylkill coal regions and Philadelphia in the early 1840s, it initiated a nearly thirty-year battle between the two transport companies, ending in 1870 when the railroad purchased the canal. The dynamics of the competition were fascinating, involving capital, technology, politics, and

¹³ Table 2.2 sources: Jones, *The Economic History of the Anthracite-Tidewater Canals*, 133, 149-154; Taylor, *Statistics of Coal*, 395, 405; Miners' Journal, *Coal Statistical Register for 1870*. Exports sent directly to New York went along the Delaware & Raritan Canal. The shipments and exports in a given year may not always add up to an even total. This is due to the fact that after some winters there was left over stock in the market which was not shipped until a year or two later.

debates over corporate privileges.¹⁴ However, because the tracks of the Reading Railroad followed a route that was fairly similar to the canal, the transition from boat to rail did not alter the geography of coal flows dramatically with the exception of coal sent directly to New York (discussed below). Therefore, this was an important transition from the perspective of how coal traveled, but not where it went.

The development of an anthracite iron trade along the paths of the canal and railroad was of greater consequence. Entrepreneurs established iron forges along the Schuylkill River at towns such as Reading, Phoenixville, and Norristown. The forges were drawn to the cheap transport offered by the canal as well as the availability of water power. As I demonstrate in Table 2.4, sites with iron forges represented around 90 percent of the consumption of anthracite along the path of the canal and railroad.¹⁵ Iron forges increased the coal consumption along the line dramatically, from under 30,000 tons in 1840 to more than half a million tons by the middle of the 1850s (Table 2.3).

Finally, some Schuylkill merchants began to send their coal directly to New York City beginning in the late 1830s. This was one area where the differences between rails and canals shaped the distribution of coal. Most of the coal sent directly to New York traveled by canals, since coal boats could travel down the Schuylkill River, around Philadelphia, up the Delaware River, and through the Delaware & Raritan canal without

¹⁴ For more information on the battle between the railroad and canal, see Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*; Jules Irwin Bogen, *The Anthracite Railroads; a Study in American Railroad Enterprise* (New York: The Ronald Press Company, 1927); Jones, *The Economic History of the Anthracite-Tidewater Canals*; Clifton K. Yearley, *Enterprise and Anthracite: Economics and Democracy in Schuylkill County, 1820-1875* (Baltimore: Johns Hopkins Press, 1961).

¹⁵ While it is possible that some of the coal used at these locations was consumed for home heating or other non-iron related purposes, it is doubtful such uses represented more than a small fraction of the consumption. For example, in 1855 Reading likely had about 20,000 residents (15,743 in 1850 and 23,886 in 1860 according to the Census). If the whole town used anthracite coal for heating, this would represent use of at most 20,000 tons, only a sixth of the total deliveries of 120,000 tons.

stopping for transshipment. The coal cars of the Reading Railroad, by contrast, had to stop at the company's wharves in Port Richmond since its tracks did not extend into New Jersey before the Civil War.¹⁶ More than 600,000 tons per year were sent along this route to New York City by the late 1850s, more than half of the total shipments on the Schuylkill canal (Table 2.3).

Table 2.3: Schuylkill Coal Flows, in Tons, 1840-1860¹⁷

Year	Canal shipments	Railroad shipments	Total shipments	Consumed along lines	Sent to Philadelphia	Direct to New York City	Shipped from Philadelphia
1840	452,291		452,291	28,924	90,000	64,388	244,680
1841	584,692	850	584,542	41,223	89,000	78,296	367,812
1842	491,608	49,902	541,510	40,584	88,000	126,554	256,080
1843	447,058	230,254	677,312	34,619		119,972	
1844	398,887	441,491	840,378	60,000		111,521	
1845	263,587	820,237	1,083,824	90,000			
1846	3,440 ¹⁸	1,233,142	1,236,582	155,460			892,464
1847	222,693	1,360,681	1,583,374	226,610	430,150		1,375,000
1848	436,608	1,216,233	1,652,841	252,837			
1849	489,208	1,115,918	1,605,126	239,290			
1850	288,030	1,428,977	1,717,007	207,863			1,075,344
1851	579,156	1,650,270	2,229,426	312,347			1,211,405
1852	800,038	1,650,912	2,450,950	322,211			1,226,488
1853	888,695	1,582,248	2,470,943	394,078		474,105	1,088,167
1854	907,354	1,987,854	2,895,208	444,161	468,232	571,081	1,411,734
1855	1,105,263	2,213,292	3,318,555	481,861	628,398	631,700	1,576,596
1856	1,169,453	2,088,903	3,258,356	520,504	660,772		1,421,213
1857	1,275,988	1,709,552	2,985,540	511,977	707,806	689,710	1,076,187
1858	1,323,804	1,542,645	2,866,449	441,166	758,471	638,832	1,029,003
1859	1,372,109	1,682,932	3,055,041	554,774	799,461		1,004,540
1860	1,356,678	1,878,156	3,234,834	608,877	800,903		1,186,477

¹⁶ As the Reading Railroad expanded its operations after the Civil War, it acquired control of several other railroads giving it direct access to the New York market.

¹⁷ Sources for Table 2.3: Jones, *The Economic History of the Anthracite-Tidewater Canals*, 41, 149-54; Miners' Journal, *Coal Statistical Register for 1870*; Taylor, *Statistics of Coal*, 395, 405; Samuel Harries Daddow and Benjamin Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development* (Pottsville, Pa.: Benjamin Bannan, 1866), 711; *Thirteenth Annual Report, Made by the Board of Trade, to the Coal Mining Association of Schuylkill County*, (Pottsville: Benjamin Bannan, 1845).

¹⁸ The canal was closed for most of this year while it was widened and deepened to allow larger boats to travel along it.

Table 2.4: Consumption Along the Path of the Reading Railroad and Schuylkill Canal, in Tons, 1855¹⁹

Station or Turnout	Reading	SNC	Station or Turnout	Reading	SNC
Port Carbon	209		Brewer's Landing		280
Schuylkill Haven	201		Port Kennedy	6,519	4,424
Orwigsburg	42	28	Norristown (iron site)	26,255	23,491
Auburn	38		Swede Furnace (iron site)	4,296	
Hamburg	445	5,807	Rambo's Limekiln	3,397	
Mohrsville	489	1,467	Bridgeport		1,464
Between Mohrsville and Reading	2,507		Plymouth		10,212
Leesport (iron site)		15,883	Conshohocken (iron site)	37,349	1,081
Felix Dam		2,384	Spring Mill (iron site)	152	28,760
Reading (iron site)	77,361	42,110	Flat Rock		303
Birdsboro' (iron site)	706	18,081	Manayunk (iron site)	1,128	11,677
Mt. Airy		112	Falls (iron site)	49,225	
Douglassville	872		Nicetown and Germantown (iron site)	14,095	
Port Union		510	Philadelphia Branch Road	537	
Pottstown (iron site)	8,986	615	Consumed Along Path	294,385	187,526
Limerick	630		Amount at iron sites	277,205	158,082
Springville		206	% Consumed at iron sites	94%	84%
Boyer's Ford	924	754	Overall iron consumption	90%	
Black Rock Dam		519	Philadelphia	342,311	286,087
Phoenixville (iron site)	57,652	16,384	Port Richmond	1,576,596	
Port Providence		481	New York City		631,700
Pauling's Dam		397			
Valley Forge	370	96	Total Coal Shipments	2,213,292	1,105,313

Coal Flows from the Wyoming Valley

The Wyoming Valley was the third anthracite coal region. The broad patterns of coal flows from this region are as follows. First, the large majority of the coal traveled to New York City along the Delaware & Hudson canal, and later on the Delaware, Lackawanna, and Western Railroad. Second, much smaller amounts of coal went north along the Hudson River to Albany and west along the Erie Canal to manufacturing cities

¹⁹ "The Coal Trade of 1855," *Miners' Journal*, January 12, 1856.

like Syracuse and Rochester. Third, some coal flowed south along the Susquehanna River to Harrisburg and Baltimore.

Coal Shipments from Philadelphia

Philadelphia and New York City were sites of coal consumption and transshipment. Coal merchants loaded anthracite onto steam vessels from wharves and shipped it to consumers up and down the eastern seaboard. The scale of this trade was enormous. By the 1850s, Philadelphians were exporting more than a million and a half tons of anthracite, representing more than 90 percent of the city's coastal trade as measured by tonnage.²⁰

Most of these shipments were directed towards other cities in the mid-Atlantic and New England. Boston was the third largest market for anthracite and began importing coal as early as 1824. Boston averaged imports of 75,000 tons of anthracite between 1835 and 1840, 140,000 tons from 1841 to 1846, 250,000 tons between 1847 and 1849, and over 400,000 tons during the 1850s.²¹ The use of this coal was fairly evenly split between home heating and industrial purposes.²² Several other cities also received shipments, including Providence, Lowell, Hartford, New Haven, Wilmington, and Albany. All of these towns were located on the seaboard or navigable rivers. The cost of transporting coal over land doubled every five miles, so any location distant from a navigable waterway was unlikely to receive shipments.

²⁰ Lindstrom, *Economic Development in the Philadelphia Region, 1810-1850*, 58.

²¹ Powell, *Philadelphia's First Fuel Crisis: Jacob Cist and the Developing Market for Pennsylvania Anthracite*, 190; Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 150.

²² Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 150.

Coal shipments from Philadelphia were used in home and industrial applications. For example, as early as 1825, workers at the Springfield Armory in Massachusetts preferred the use of anthracite for making gun barrels.²³ In 1831, the *Miners' Journal* reported that anthracite coal was being used for making bricks in New Orleans.²⁴ In 1832, *Niles Weekly Register* documented the varied use of anthracite in Rhode Island mills, demonstrating that the coal was employed for dyeing, print-making, and heating purposes.²⁵ Beginning in the mid-1830s, the Lowell textile mills began importing significant quantities of anthracite for heating and manufacturing purposes.²⁶

Coal did not flow everywhere. Most importantly, very little anthracite was delivered south of Baltimore (Table 2.6). Some of this discrepancy is explained by climate: the warmer winters and larger forest reserves of the south meant that the home heating market was less promising. However, the south also trailed the north in the industrial consumption of anthracite. Much has been written about the different industrial development patterns of the north versus south in antebellum America.²⁷ To the extent that coal was an enabling factor for industrialization (and I argue throughout this work that it was very important in this capacity) the evidence of coal flows offers another explanation for the divergent economic histories of the north and south.

Foreign trade never became an important part of the anthracite trade. Small quantities were shipped to Caribbean islands (part of Philadelphia and New York's participation in the Triangle Trade) but these exports were only a fractional component of

²³ Louis Hunter, *A History of Industrial Power in the United States, 1780-1930: Steam Power* (Published for the Hagley Museum and Library by University of Virginia Press: Charlottesville, VA, 1985), 416.

²⁴ "Untitled," *Miners' Journal*, April 9, 1831.

²⁵ "Rhode Island Manufactures," *Niles Weekly Register*, February 27, 1832.

²⁶ "Lowell Factories," *Niles Weekly Register*, November 8, 1834.

²⁷ A good overview can be found in Walter Licht, *Industrializing America: The Nineteenth Century* (Baltimore: Johns Hopkins University Press, 1995).

the overall shipments. Despite the hope of some boosters to develop an international trade, the cheap price of anthracite coal undercut the potential of this market due to its general bulk. Simply put, anthracite had a weight-value ratio that was not conducive to large-scale shipments across the ocean.²⁸

Table 2.5: Anthracite Shipments from Bristol, in Tons, 1832²⁹

Location	Tons	Location	Tons
Boston	1616	New Haven	1614
Albany	1698	New York	585
Hartford, Conn	700	Salem, MA	702
Portsmouth	138	Troy, NY	507
West Point	526	Baltimore	193
Wilmington, DE	160	Providence, RI	174
Newport, RI	245	Wareham, MA	291
Fall River	166	Alexandria	65
New Bedford	144	Somerset	360
Portsmouth, NH	110	Taunton	294
Schenectady	80	Plymouth	110
Chester	50	Poughkeepsie	25

Table 2.6: Anthracite Shipments from Philadelphia's Port Richmond, in Tons, 1855³⁰

Regional destination	Total tonnage
New England (Massachusetts: 553,074; Rhode Island: 98,090; Connecticut: 60,796; Maine: 33,528; New Hampshire: 15,518)	770,006
Mid-Atlantic (New York: 523,312; New Jersey: 52,850; Baltimore: 10,615; Delaware: 7,760)	594,537
South & West (Virginia: 22,721; South Carolina: 29,568; Georgia: 4,023; California: 3,547; North Carolina: 4,112; Florida: 3,312; New Orleans: 3,294; Alabama: 2,125; Washington, DC: 16,754)	89,456
Foreign Exports (Includes Cuba, Nicaragua, Jamaica, Montevideo, Rio, San Juan, St. Johns, St. Michaels, and Thomaston)	17,232
Total	1,471,231

²⁸ For a contemporary (and skeptical) analysis of the possibilities of foreign trade in anthracite, see: Richard C. Taylor, *Establishment of an American Coal Trade with Europe* (Philadelphia: S.n., 1843).

²⁹ "The Coal Trade," *Hazard's Register*, February 23, 1833.

³⁰ "Coal Trade," *Miners' Journal*, December 29, 1855.

Consuming Coal, Creating the Mineral Economy

Once coal was delivered to consumers, how was it used? What were the effects of these new practices? As I show throughout this section, the consumption of coal by mid-Atlantic residents broke the connections between land, energy, and society that had characterized the region's traditional relationships with energy. The millions of tons of coal traveling along the anthracite canals generated new structural possibilities for the expansion of cities, industrial operations, and transportation. Consumers used anthracite in homes, iron furnaces, steam engines, and factories. Collectively, these practices began the transition to a mineral economy in the mid-Atlantic by the outbreak of the Civil War.

Home Heating

Home heating was the most common and widespread use of anthracite coal. By the turn of the nineteenth century, the heating demands of cities such as Philadelphia, New York, and Boston were putting a strain on their timber hinterlands. The cost of firewood had nearly tripled over the latter half of the eighteenth century by some calculations, rising at a greater rate than food, clothing, or housing.³¹ By the 1820s, commentators were wondering whether cost of firewood would limit the growth of eastern seaboard cities.³² The mid-Atlantic's reliance on organic energy sources for home heating was subject to the negative feedbacks of a Malthusian world.

People worried about the firewood supply for two reasons. First, many of the forests near Philadelphia, New York, and Boston had been cut down over the course of

³¹ Adams, "Warming the Poor and Growing Consumers: Fuel Philanthropy in the Early Republic's Urban North," 69.

³² "Exposition."

the seventeenth and eighteenth centuries. In the nineteenth century, wood was arriving from further and further distances up the Schuylkill, Delaware, and Hudson rivers. Second, it took a lot of wood to keep a family warm through a northeast winter. A poor family in Philadelphia needed at least two and a half cords of wood each winter.³³ Families with larger households and more means consumed much more wood. A wealthy writer in the early 1830s noted that his household burned twenty-four cords of wood a winter.³⁴ On average, eight cords of wood for the year likely represented a reasonable expectation for a family's needs.³⁵ As cities grew larger over the first two decades of the nineteenth century, urbanites' increasing demand for wood strained the available resources.

Anthracite boosters were quick to argue that coal was a compelling substitute. Unlike the decline of forests along the mid-Atlantic's rivers, the mines of the anthracite region showed signs of practically limitless bounty. Articles promoting the use of anthracite argued that it would take about one ton of coal per month during the six cold months of the year to keep a family warm.³⁶ As the typical Philadelphia household held roughly six people, we can assume that one ton of coal per person was needed each winter.³⁷

Anthracite boosters had to overcome several challenges to convince consumers to switch fuel sources. Consumers had to invest in a specially designed stove or grate and

³³ A cord of wood was measured as a stack four feet wide, four feet high, and eight feet long. The estimate of two and a half cords was made by the Philadelphia Fuel Savings Society, an organization helping poor people offset the high costs of wood during the winter: "Fuel Savings Society."

³⁴ "Anthracite Coal, Versus Wood."

³⁵ "Coal and Wood," *Hazard's Register*, October 10, 1829.

³⁶ "The Economy of Heat," *Hazard's Register*, February 23, 1833.

³⁷ According to the 1860 Census, the average number of persons per dwelling was 5.98 in 1850 and 5.64 in 1860. United States Bureau of the Census, *Census of Population, 1860* (Washington, D.C.: Government Printing Office, 1862), xxvii.

alter their heating and cooking practices. Because burning anthracite in a stove meant abandoning the pleasant flame of an open hearth, many objected on aesthetic grounds. Anthracite boosters adopted several strategies to counter these difficulties. Scientists performed experiments demonstrating the superior heating qualities of anthracite.³⁸ The Fuel Savings Society, a philanthropic organization, contracted with the Steinhaur & Kisterbock company to build stoves costing only \$5.50, making it cheaper for consumers to switch over.³⁹ In fact, this period saw extensive experiments with stove design, many of which were constructed to burn anthracite. Priscilla Brewer notes that between 1815 and 1839, there were 329 patents for stove designs, representing nearly four percent of the Patent Office's awards.⁴⁰ Josiah White had his wife keep an anthracite fire burning in their Philadelphia home so that prospective customers could see how it worked.⁴¹

Starting and maintaining an anthracite fire was difficult. In his guide to servants, Robert Roberts devoted fifteen pages to the process, covering everything from buying coal, breaking it, starting a fire, and keeping it going. As the author prefaced his instructions: "Very few servants at first understand the method of kindling and continuing a fire of Lehigh coal, many will never learn, and many more from erroneous instructions, whilst they think they understand it, make but a bungling piece of work of it... it must be granted that a knowledge of how to make a Lehigh coal fire, when it is becoming so common in this country, is quite an acquisition." The descriptions include such advice as breaking the coal into the right size pieces ("about as large as your fist, if your hand is

³⁸ Bull, *Experiments to Determine the Comparative Value of the Principal Varieties of Fuel Used in the United States, and Also in Europe and on the Ordinary Apparatus Used for Their Combustion*.

³⁹ "Fuel Savings Society."

⁴⁰ Priscilla J. Brewer, *From Fireplace to Cookstove: Technology and the Domestic Ideal in America* (Syracuse, N.Y.: Syracuse University Press, 2000), 64.

⁴¹ Knies, *Coal on the Lehigh, 1790-1827: Beginnings and Growth of the Anthracite Industry in Carbon County, Pennsylvania*, 52.

rather a small one”), using the right kindling (“charcoal, unless dry hickory be preferred”), keeping the fire going (“judicious use of the poker is essential to the well-being of an anthracite fire”), as well as an analysis of the relative merits of anthracite (“I place *cleanliness* at the top of its virtues,—cleanliness as to smoke, dust, and smell”).⁴² Using anthracite was not a simple or intuitive process.

Despite the challenges of conversion, many homes began using anthracite for heating purposes in the middle of the 1820s. This was a gradual process, beginning with no homes heated with coal in 1820 to widespread adoption by the Civil War. By 1830, the total receipts for coal sales in Philadelphia City and County were \$308,400.⁴³ This indicates that a small but growing percentage of the population was already using coal in homes at the time. Anthracite was selling at \$6.50 per ton in Philadelphia during these years, meaning that a maximum of 47,446 tons of coal were sold in the marketplace. Assuming 20 percent of the coal was bituminous from Liverpool, Virginia, and Nova Scotia, this leaves about 38,000 tons of anthracite coal in the market.⁴⁴ Given that the population of Philadelphia City and County in this year was 188,797 and assuming usage of one ton per person, this gives a maximum adoption of coal for home heating of 20 percent, supposing that all the coal was used in this capacity. However, contemporary reports suggest that more coal was used in industry than in homes. An 1831 report in a trade journal argues that “[m]ore than one-half of the whole quantity of Anthracite Coal, mined and brought to market, has been consumed by steam engines and in

⁴² Robert Roberts, *The House Servant's Directory: Or a Monitor for Private Families ...* (Boston: Munroe and Francis, 1827), 159-73.

⁴³ "Report of the Committee of the Senate of Pennsylvania Upon the Subject of the Coal Trade," 43.

⁴⁴ This number is consistent with the shipping data from the Schuylkill and Lehigh canals, which indicate shipments to Philadelphia of 34,127 tons. Given that there was a small inventory from the previous year, 38,000 is a reasonable approximation.

manufactories.”⁴⁵ Therefore, assuming that around half of the anthracite coal was used in domestic heating, about 10 percent of Philadelphia’s home heating needs came from anthracite in 1830.

New York City appears to have followed a similar pattern of adoption of anthracite. By 1831, the city was sufficiently dependent on anthracite that market shortages led to widespread panic.⁴⁶ Like Philadelphians, New Yorkers used anthracite in factories and steam engines as well as for home heating. Therefore, at the beginning of the 1830s, it is likely that an adoption rate of approximately 10 percent held for New York as well (assuming that about half of New York’s 50,162 tons of anthracite used in 1832 and 53,882 tons used in 1833 were for home heating).⁴⁷

Over the 1840s and 1850s, there was a synergistic pattern between increased shipments of anthracite, lower coal prices, and the widespread distribution of stoves. By 1850, it was estimated that ninety percent of houses in the northern states used stoves for home heating.⁴⁸ While we do not know for certain what fuel was used in these stoves, anthracite was the cheapest and most abundant fuel in cities like Philadelphia and New York at the time. A ton of anthracite cost between \$4.50 and \$5.00 wholesale in Philadelphia in 1850 while a cord of wood in the 1830s already cost between four and seven dollars in the Quaker City depending on whether it was purchased in summer or winter.⁴⁹ Given that a ton of coal had greater heating capacity for lesser cost, it is

⁴⁵ "Anthracite Coal," *Hazard's Register*, Dec 24, 1831.

⁴⁶ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 17.

⁴⁷ "Coal Trade," *Hazard's Register*, Mar 7, 1835. "Fuel," *Hazard's Register*, May 4, 1833.

⁴⁸ Brewer, *From Fireplace to Cookstove: Technology and the Domestic Ideal in America*, 98.

⁴⁹ Taylor, *Statistics of Coal*, 455; Adams, "Warming the Poor and Growing Consumers: Fuel Philanthropy in the Early Republic's Urban North."

reasonable to infer that three-quarters of Philadelphia and New York City's populations were using anthracite by 1850.

By 1860, the adoption of anthracite for home heating in Philadelphia was practically universal. If a Boston physician in 1868 could report that 99 out of 100 homes in that city were heated by anthracite, it is fair to assume that a similar ratio held in Philadelphia by 1860, since anthracite was both cheaper and more easily available.⁵⁰ With a population of 565,529 in 1860, citizens of Philadelphia City and County was likely burning between 500,000 and 600,000 tons of anthracite per year to keep warm. This was approximately half of the coal delivered to Philadelphia that year (800,903 arrived from the Schuylkill region and approximately 200,000 additional tons arrived from the Lehigh region).

I have collated this information in Table 2.7 to estimate the total consumption of anthracite for home heating in Philadelphia and New York City. It is important to realize that much more was consumed for home heating purposes in other cities including Boston, Providence, New Haven, and Albany. As discussed above, home heating required about one ton of coal per person per winter, so multiplying the population by the adoption rate provides an estimate total consumption for home heating purposes. The adoption percentage is based on calculations from 1830, 1850, and 1860, and assumes a steady rate of growth in the interim period.

⁵⁰ George Derby, *An Inquiry into the Influence Upon Health of Anthracite Coal When Used as Fuel for Warming Dwelling-Houses* (Boston: A. Williams and Co., 1868), 6.

Table 2.7: Estimated Coal Consumption in Home Heating, Philadelphia and New York City, in Tons, 1830-1860⁵¹

Year	Philadelphia population (city and county)	Adoption rate (estimate)	Consumption, in tons (estimate)	New York City population	Adoption rate (estimate)	Consumption, in tons (estimate)
1830	188,797	10%	20,000	202,589	10%	20,000
1840	258,037	40%	105,000	312,210	35%	110,000
1850	408,792	75%	305,000	515,547	70%	360,000
1860	565,529	90%	510,000	813,669	85%	690,000

What were the effects of using anthracite coal in the home, and how did this contribute to the shift from the organic to mineral economy? First, it changed people's experience of home heating. The introduction of coal likely made houses warmer and more comfortable for most consumers because of its lower cost and higher heat output.⁵² It also altered the gender dynamics of household labor. The gathering, sawing, and stacking of firewood was usually performed by men. An efficient coal stove saved the man's work of gathering fuel but not the woman's work of cooking or cleaning the stove.⁵³ Substituting coal for wood thereby shifted the relative balance of housework from men to women. Finally, buying coal integrated some families further into the market economy by substituting the collection of wood by personal exertion with cash purchases of anthracite.

Over the long term, the substitution of coal for firewood also helped to push the mid-Atlantic towards a mineral economy. This can be seen most clearly through considering the amount of firewood that would be necessary to support the population of the mid-Atlantic's burgeoning cities. For example, in 1860, 565,529 people lived in the City and County of Philadelphia. Given that about 1.25 cords of wood were needed per

⁵¹ Population numbers from Andriot, *Population Abstract of the United States*.

⁵² Anecdotal evidence confirming that anthracite fires kept houses warmer is found in several testimonial letters. See, for instance: "Anthracite Coal, Versus Wood."

⁵³ Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave* (New York: Basic Books, 1983), 61.

person per winter for heating purposes, and at least another quarter of a cord was needed for cooking, we can estimate a minimal need of 1.5 cords of wood per person. Philadelphia in 1860 therefore would have required at least 850,000 cords of wood just to support the living needs of its population. Under nineteenth century forestry practices, about 2/3 of an acre was needed to produce a sustainable yield of one cord of wood.⁵⁴ Therefore, Philadelphia would have required a dedicated wood hinterland of 567,000 acres (~885 square miles or roughly 1/50th of Pennsylvania) to support the heating and cooking needs of its population.

It was technically possible for Philadelphians in 1860 to have met their heating needs with wood, but it would have required difficult trade-offs. The city could have created a large wood reserve, although any land that was near transportation facilities would have been more highly sought after as farmland. More likely, Philadelphians would have relied on the vast timber resources of Maine and North Carolina to fill the gap. However, the additional requirements on these forests by residents of eastern seaboard cities would have significantly raised the cost of firewood and increased the rate of exhaustion. It would have also driven up the price of lumber, thereby making housing more expensive since most American buildings were made out of wood at the time.⁵⁵ Therefore, the use of anthracite in home heating preserved trees for lumber, keeping building supply prices down. In other words, while Philadelphia could have supported its population in 1860 with firewood instead of anthracite, this would have required more

⁵⁴ Under good conditions in the nineteenth century, an acre of land could produce 30 cords of wood if clearcut, and would take 20 years to re-grow. With poor soil or indifferent forestry practices, the yield would likely be lower. Thus, an estimate of 1.5 cords of wood per acre, or two-thirds an acre for one cord of wood is a reasonable, if optimistic, estimate. Williams, *Americans and Their Forests: A Historical Geography*, 106.

⁵⁵ In 1839, 84% of the 54,000 newly constructed houses were made out of wood. *Ibid.*, 147.

land and the zero-sum trade-offs that were characteristic of an organic economy. In addition, these changes would have become more acute as Philadelphia's population grew to 675,000 in 1870, 875,000 in 1880, and over a million by 1890.⁵⁶ As a cheap heating fuel, anthracite removed a significant constraint to the growth of nineteenth century cities and represented an important step into a mineral economy.

Iron Manufacture

The application of anthracite coal to iron manufacture provides one of the clearest examples of the development of a mineral economy in the mid-Atlantic. Once the technical problems associated with forging iron with anthracite were solved in 1840, the industry expanded at an exponential pace. Anthracite forges consumed huge quantities of coal, reshaped the geography of iron manufacture, and played an important role in stimulating the industrialization of America.

Iron manufacture is a complex chemical and engineering process and figuring out how to use anthracite for this purpose was not easy. The smelting fuel had to serve several functions: supplying heat, providing structural support, and removing impurities from the ore. Anthracite boosters led several efforts to overcome these technical challenges. The Franklin Institute, a scientific association in Philadelphia, offered its prestigious gold medal prizes to anyone who could forge iron with anthracite; a group of wealthy men including Nicholas Biddle offered a \$5,000 reward to anyone who could keep an anthracite forge in operation for three months; and the State of Pennsylvania granted favorable corporate charter privileges to companies forging iron with

⁵⁶ New York City grew even more quickly during this period, with 942,292 people in 1870, 1,206,299 in 1880, and 1,515,301 in 1890.

anthracite.⁵⁷ The Lehigh Coal & Navigation Company sent officers to Wales to learn about new techniques. Despite the interest and attention of several parties, it still took years of experimentation until the technical problems were solved. By 1840, several groups began to have success, drawing heavily on the expertise of ironmasters in Wales who were using Welsh anthracite to forge iron.⁵⁸

Once boosters addressed the technical problems, the anthracite iron industry grew rapidly. Within seven years, more than forty forges were producing over 150,000 tons of iron. Despite a temporary decline in production caused by the rescinding of protective tariffs in the late 1840s, output increased from practically nothing in 1840 to more than half a million tons annually at the outbreak of the Civil War. By 1855, iron masters in the United States were producing more iron with anthracite than any other fuel source.

The expansion of anthracite iron production was predicated on the ever-increasing supply of coal to its forges. After the domestic heating market, the iron industry became the single largest user of anthracite coal. Given that there were relatively stable ratios between the amounts of iron produced and the amounts of coal consumed, we can approximate the total consumption of coal each year. About two tons of anthracite coal were needed to produce a ton of pig iron. An additional quarter ton of coal per ton of pig iron was necessary to fuel a steam engine to operate bellows if a forge was not located at a site water power was available.

⁵⁷ Cochran, *Frontiers of Change: Early Industrialism in America*, 93.

⁵⁸ The winner of Biddle's \$5,000 prize was a man named William Lyman who hired Benjamin Perry from the Pentyweyn Iron Works in South Wales to run his forge. In addition, the Lehigh Crane Iron Company began operations under the leadership of David Thomas, who had worked under George Crane in Wales. Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 65.

Once pig iron was produced, much of it was reprocessed to form products such as rails, nails, and plates. Significant quantities of anthracite coal were used in these operations, although it is more difficult to determine the exact amount. It took an additional two tons of coal to roll or puddle iron and a ton of steel required as much as eight tons of coal in its preparation. In the absence of clear data on the consumption of anthracite in rolling operations, it is nevertheless possible to obtain estimates through interpreting the existing data. First, in 1847, a year for which good data exists, there was a total production of 151,331 tons of pig iron, and the entire industry was said to consume 483,000 tons of anthracite.⁵⁹ If roughly 300,000 tons were used to produce the pig iron, that leaves about 180,000 tons used in secondary processing, or an additional 60 percent. Second, from the study of coal consumption along the path of the canals in the Schuylkill and Lehigh Valleys, we reach similar numbers. As shown below in Table 2.9, the Lehigh and Schuylkill Valleys produced about half of the total anthracite iron production. In 1855, for example, total pig iron production was 381,866 tons. Assuming that about half of this was made in the Lehigh and Schuylkill Valleys (190,000 tons) this would have required 380,000 tons of coal. The regions consumed about 639,825 tons of coal in iron production, leaving a balance of 259,825 tons, or 68 percent more. Finally, in 1860, total pig iron production was 519,211 tons, with an estimated 260,000 produced in the Schuylkill and Lehigh regions. About 885,000 tons of coal were consumed in the region, which leaves a balance of about 365,000 tons of coal used in secondary iron operations or a ratio of 70 percent more than in pig iron production. Therefore, assuming a ratio of 65

⁵⁹ C. G. Childs, *The Coal and Iron Trade, Embracing Statistics of Pennsylvania* (Philadelphia: C. G. Childs, 1847), 24.

percent more coal used in secondary processing gives a reasonable estimate of the total consumption.

These calculations are summarized in Table 2.8. I have rounded the calculations to the nearest 5,000 tons to indicate the limits of precision in calculating the data. Two trends are particularly important to note. First, the expansion of coal consumption in anthracite production was remarkable, increasing from practically nothing before 1840 to half a million tons in 1847 and quadrupling again by the middle of the Civil War. Second, from the 1850s, anthracite iron steadily represented about 20 percent of all anthracite shipments. The energy landscape of anthracite transport kept pace with the iron industry's ravenous appetite for coal.

Table 2.8: Estimated Anthracite Consumed in Iron Production, in Tons 1847-1864⁶⁰

Year	Anthracite iron production (in tons)	Coal used for pig iron production (estimate)	Coal used in secondary iron processing (65%) (estimate)	Anthracite used in iron industry (estimate)	All anthracite shipments	% of total
1847	151,331	305,000	200,000	505,000⁶¹	2,284,659	22%
1849	109,166	220,000	145,000	365,000	3,027,708	12%
1854	339,435	680,000	440,000	1,120,000	5,086,391	22%
1855	381,866	760,000	495,000	1,255,000	5,876,872	21%
1856	443,113	885,000	575,000	1,460,000	6,607,517	23%
1857	390,385	780,000	505,000	1,285,000	6,896,351	19%
1858	361,430	720,000	470,000	1,190,000	6,644,941	18%
1859	471,745	940,000	610,000	1,550,000	6,802,967	23%
1860	519,211	1,040,000	675,000	1,715,000	7,808,255	22%
1864	684,519	1,370,000	890,000	2,260,000	9,566,006	24%

⁶⁰ Sources for Table 2.8: Anthracite iron production numbers are from Bartholomew, Metz, and Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley*, 52-53; *Proceedings of the American Iron and Steel Association at Philadelphia*, Nov. 20, 1873, (Philadelphia: Chandler, 1873), 51; Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 698; "Henry Clay in Philadelphia," *Miners' Journal*, August 10, 1850. Coal used for pig iron production is estimated by multiplying anthracite iron production by two. Given that this does not include any coal for firing steam engines, this number is a conservative estimate. Coal used in secondary iron processing is calculated by multiplying coal use in pig iron production by 65% as described in the text. Anthracite used in iron industry is the addition of the previous two columns. All data for anthracite shipments are from: *Miners' Journal*, *Coal Statistical Register for 1870*.

⁶¹ According to contemporary sources, the actual amount of anthracite used in the iron industry that year was 483,000 tons. Childs, *The Coal and Iron Trade, Embracing Statistics of Pennsylvania*, 24.

Table 2.9: Coal Consumed in Iron Production in the Schuylkill and Lehigh Valleys, 1840-1860⁶²

Year	Coal consumed on SNC and Reading RR	Coal consumed on LC&NC	Coal consumed on Lehigh Valley RR	Coal consumed in Lehigh and Schuylkill Valleys	Amount likely consumed in iron production
1840	28,924	23,955		52,879	10,576 (20%)
1845	90,000	(81,726)		171,726	103,035 (60%)
1850	207,863	117,119		324,982	259,986 (80%)
1855	481,861	229,056		710,917	639,825 (90%)
1860	608,877	(174,462)	(200,000)	983,339	885,005 (90%)

The anthracite iron industry operated as a mineral economy. This is most clearly seen by comparing its development to the charcoal iron industry. Americans had been forging iron with charcoal (wood burned in the near absence of oxygen) for many decades and Pennsylvania's large forests supplied much of the nation's needs. However, the dependence on organic energy sources meant that the charcoal iron industry differed in two fundamental ways. First, its output was subject to the limits of available land. Second, it had a completely different geography.

Land was the great constraint for the charcoal iron industry. A typical early nineteenth century forge producing 600 tons of iron a year required the charcoal equivalent of one acre a day of timber for its operations. This meant that for sustainable development (assuming 300 days of operation a year and 30 years to reforest land), the iron company would need a 9,000 acre plantation for sustainable operations.⁶³ While there were plenty of available forests left in Pennsylvania in 1860, the dependence on land still presented finite limits for the expansion of charcoal iron production. Moreover,

⁶² Sources for Table 2.9: Coal consumed on the lines is taken from data tables earlier in the chapter (Tables 2.1, 2.2, and 2.3). The Lehigh Valley RR began operations in 1855 and delivered nearly 500,000 tons of coal along its line in 1865 according to: Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 7105. Therefore, I have estimated its deliveries in 1860 as 200,000. The consumption estimates are based on calculations from Table 2.4 which showed that 90% of the consumption along the paths of the Schuylkill carriers was for iron production in 1855. The earlier estimates assume a steady rate of growth.

⁶³ Bartholomew, Metz, and Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley*, 6.

because charcoal is a brittle substance, it cannot be transported far overland without breaking into small and unusable pieces. This meant that there were limits to the total energy supply that could be gathered at a single location, resulting in several decentralized forges with relatively small outputs.⁶⁴

The anthracite iron industry, by contrast, did not encounter these limits. The increase in output of anthracite forges was impossible for the charcoal industry to replicate. Table 2.10 documents the total output of iron by the two sources. Anthracite iron output increased dramatically. While the charcoal industry continued to grow, its relative share of the industry dropped significantly. Moreover, the average charcoal furnace produced much less iron than the average anthracite forge—730 versus 3,783 tons per year in 1847.⁶⁵ Even though more charcoal furnaces (67) were opened than anthracite forges (36) between 1842 and 1846, the total output of the charcoal furnaces only totaled 75,200 tons versus 103,000 tons for the anthracite furnaces.⁶⁶

⁶⁴ Siefertle argues that there is a natural limit of 2,000 tons annual production for a charcoal forge based on the limits of charcoal transport: Siefertle, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 64.

⁶⁵ Bartholomew, Metz, and Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley*, 52-3; Childs, *The Coal and Iron Trade, Embracing Statistics of Pennsylvania*, 23.

⁶⁶ Childs, *The Coal and Iron Trade, Embracing Statistics of Pennsylvania*, 23.

Table 2.10: U.S. Iron Production By Fuel Source, in Tons, 1847-1864⁶⁷

Year	Anthracite	% of total	Bituminous and coke	% of total	Charcoal	% of total
1847	151,331	38.9	17,800	4.6	219,674	56.5
1849	109,166 ⁶⁸				175,174	
1854	339,435	46.1	54,485	7.4	342,298	46.5
1855	381,866	48.7	52,390 or 62,390	8.0	339,922	43.3
1856	443,113	50.2	69,554	7.9	370,470	41.9
1857	390,385	48.9	77,451	9.7	330,321	41.4
1858	361,430	51.3	58,351	8.3	285,313	40.5
1859	471,745	56.1	84,841	10.1	284,041	33.8
1860	519,211	56.5	122,228	13.3	278,331	30.3
1864	684,519	59.5	210,108	18.3	255,486	22.2

By the 1860s, the production of the anthracite iron industry exceeded the organic limitations of Pennsylvania's charcoal iron production. By 1820, coal-fueled British iron production had already exceeded the capacity of its total landmass if charcoal had been the fuel. A similar dynamic began to appear in Pennsylvania during this period.⁶⁹ Given the ratio of 9,000 acres of land for the sustainable yield of 300 tons of iron, Pennsylvania's landmass could generate enough energy for a maximum capacity of 982,500 tons of iron.⁷⁰ By 1860, there were already 519,211 tons of pig iron produced with anthracite in addition to 278,331 tons with charcoal (approximately 80 percent of the nation's anthracite iron and 50 percent of the charcoal iron was being produced in Pennsylvania). By 1869 the iron production of Pennsylvania from all sources would have exceeded the sustainable limits of organic energy sources. National iron production that year was approximately 1.9 million tons, about 1.25 million tons of which were produced in Pennsylvania. Most of Pennsylvania's iron, about 800,000 tons, was forged with

⁶⁷ Sources for Table 2.10: Bartholomew, Metz, and Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley*, 52-53; *Proceedings of the American Iron and Steel Association at Philadelphia*, Nov. 20, 1873, 51; Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 698; "Henry Clay in Philadelphia."; Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 66.

⁶⁸ The decline from 1847 to 1849 was a result of the U.S. dropping its tariff on foreign iron. Cheap iron from Britain flooded the market and cut into domestic production.

⁶⁹ Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 103.

⁷⁰ Pennsylvania's area is 46,055 square miles, or 29,475,200 acres.

anthracite.⁷¹ By 1880, anthracite iron production reached 1,807,651 tons—a level of production that was impossible in an organic economy.⁷²

The anthracite industry also operated in a radically different geography. Because charcoal iron forges required acres of land, they were disproportionately located in rural areas where there were no competing demands for the forests. This meant that charcoal iron production was decentralized and there were high costs for the transport of its products. By contrast, anthracite iron forges were densely concentrated along the banks of the canal network. As shown in Table 2.11, the industry was concentrated into five distinct regions, each connected to one of the anthracite canals.⁷³ By 1856, there were 121 anthracite iron furnaces nationwide, and 93 of them were in eastern Pennsylvania.⁷⁴ In 1873, there were at total of 202 anthracite iron furnaces, and only two were not in the eastern mid-Atlantic—one in Massachusetts and one in Virginia.⁷⁵

⁷¹ Anthracite iron production for the nation was 971,150 tons, about 80% of which was produced in Pennsylvania. In addition, there were 392,150 tons made with charcoal and 553,341 with coke and bituminous. At least half of this production came from Pennsylvania. Bartholomew, Metz, and Bartholomew, *The Anthracite Iron Industry of the Lehigh Valley*, 53.

⁷² Ibid.

⁷³ The Lehigh Valley was the clear leader, with several of the largest iron forges. The Schuylkill Valley had many iron furnaces, particularly in Reading, Phoenixville, and the towns just outside of Philadelphia. The Lower Susquehanna River area included forges in Harrisburg and Lancaster County. The Upper Susquehanna River area included the iron forges of Wilkes-Barre and Scranton. The Eastern region included the iron production of New Jersey and New York, most of which occurred along the Hudson River and Morris Canal.

⁷⁴ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 64.

⁷⁵ *Proceedings of the American Iron and Steel Association at Philadelphia*, Nov. 20, 1873, 49.

Table 2.11: Location and Output of Anthracite Iron Furnaces, 1864⁷⁶

Region	# of furnaces	In blast in 1865	1864 production (in tons)	Coal used (in tons)	Ore used (in tons)	Ore used per ton	Coal used per ton
Lehigh	30	22	214,093	459,051	486,105	2.33	2.15
Schuylkill	24	20	112,806	227,000	259,000	2.3	2
Lower Susquehanna	32	22	118,615	228,886	271,762	2.33	2
Upper Susquehanna	29	16	108,664	213,477	261,015	2.6	2
Eastern	31	10	130,140	256,147	242,485	1.8	2
Totals	146	90	684,519	1,384,561	1,520,367		

This geographic concentration did not occur by accident—it was shaped by the energy landscape of anthracite canals. First, enterprises could only obtain the quantities of iron necessary for iron production at a competitive price along the paths of a canal. Second, the canals facilitated the movement of other goods related to the iron industry, including iron ore, limestone, and finished goods. The cost of shipping iron to Philadelphia or New York from inland rural furnaces was typically five to eight dollars per ton, whereas canal boats could deliver iron for as little as a dollar per ton.⁷⁷ Finally, canals offered water-power that could operate the furnace bellows, thereby lowering operating costs. Therefore, canals did not just shape the flows of coal, they also structured the geographies of energy-intensive industries as well. If the anthracite canals were the backbone of the new energy landscape, it is not surprising that iron forges, the society's most energy-intensive industry, attached themselves like ribs.

Moreover, the dense concentration of anthracite iron forges did not require social trade-offs regarding land use. Coal made it possible to increase iron production without sacrifices in other domains. For example, in 1864, there were 30 furnaces in the Lehigh Valley that used nearly 500,000 tons of coal to produce more than 200,000 tons of iron in

⁷⁶ Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 698.

⁷⁷ Miller and Sharpless, *The Kingdom of Coal: Work, Enterprise, and Ethnic Communities in the Mine Fields*, 64.

an area of only 730 square miles.⁷⁸ This density of production was impossible in an organic economy. Characteristic of a mineral economy, however, the Lehigh Valley's agricultural output increased at the same time as its iron and coal industries expanded. The region's production of grain, corn, oats, and dairying grew during the 1840s and 1850s.⁷⁹ The new structural relationships between land, energy, and society are clearly indicated by the fact that the region could increase multiple areas of economic activity at the same time without needing to decide between alternatives.

Steam Engines

The development of the steam engine has been widely recognized as one of the crucial drivers of industrialization. By transforming heat into motion, steam engines created the potential for new types of machinery that could transform work, production, and transport. Of course, these revolutionary effects were dependent on cheap and abundant sources of heat. At first, organic sources sufficed. The first fleet of steam vessels in the mid-Atlantic relied on wood. However, organic sources could not support patterns of ever-increasing use of steam engines. As early as 1830, steam vessels had contributed to the deforestation of large parts of New Jersey and the land along the Delaware and Hudson rivers. Over the next several decades, steam engines and anthracite coal worked in a synergistic manner to transform the region's factories, coal mines, and transport systems.

⁷⁸ Total production in the Lehigh Valley in 1864 was 214,093 tons consuming 486,105 tons of anthracite. Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 698. Area information from Lehigh Valley Convention and Visitor's Bureau Home Page: <http://www.lehighvalleypa.org/> [accessed September 18, 2008].

⁷⁹ Brzyski, "The Lehigh Canal and Its Economic Impact on the Region through Which It Passed, 1818-1873", 711-722.

Steam Engines in Manufacturing

The first American steam engines were stationary installations that provided power for industrial enterprises. Before the spread of steam engines, most American industrial power came from muscles and water mills.⁸⁰ For example, in 1820, there were as many as one hundred water wheels for each steam engine.⁸¹ This made sense in an organic economy. Water power was relatively cheap and offered the densest concentration of energy in a single location. However, reliance on water power had geographic consequences. First, it was an inflexible energy source. Water power was only available at points where rivers fell. Second, the energy could not be transported away from the river banks.⁸² As a result, water power was similar to charcoal iron production in that energy supply necessitated a decentralized distribution of largely rural manufacturing establishments.

The development of New England industries reflects the geographic logic of water. Most mills were established in rural areas where falling water was available.⁸³ The possibilities and limitations of water power are most clearly embodied by the great textile mills at Lowell. While the company was generally profitable, in large part due to the cheap water power, the site had disadvantages. The Lowell entrepreneurs invested

⁸⁰ For an overview of American energy technologies in the industrialization process, see: Louis C. Hunter, *A History of Industrial Power in the United States, 1780-1930* (Charlottesville: Published for the Eleutherian Mills-Hagley Foundation by the University Press of Virginia, 1979).

⁸¹ Jeremy Atack, Fred Bateman, and Thomas Weiss, "The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing," *Journal of Economic History* 40, no. 2 (1980): 282. The authors document the presence of 43 American steam engines in 1820.

⁸² The energy of falling waters was usually transferred to machinery by leather belts, gears, and pulleys. The friction associated with these devices created a maximum limit to the distance the energy could be transported on the order of hundreds or at most a few thousand feet. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 193-95.

⁸³ For example, see Judith McGaw's study of mechanization in the Berkshire paper-making industry: Judith A. McGaw, *Most Wonderful Machine: Mechanization and Social Change in Berkshire Paper Making, 1801-1885* (Princeton, N.J.: Princeton University Press, 1987).

millions of dollars to create a factory system that would capture the large energy supply of the Merrimack River. Because few people lived in the immediate area, the company's directors had to go to elaborate lengths to attract workers, house them, import supplies, and export finished products, thereby forcing them to address a range of labor and material problems. In addition, the overall output of the site was limited by the energy capacity of the Merrimack River.⁸⁴

Steam engines operated according to a different logic. In those sites where abundant and cheap heat was available, steam engines could support industrial growth without the limits of the organic economy and in a geographically flexible manner. The energy landscape of anthracite coal meant that the mid-Atlantic was uniquely privileged to take advantage of steam engines, particularly in the region's metropolises. Between 1820 and 1860, Philadelphia and New York took pioneering roles in the adoption of steam engines, thereby laying the groundwork for an urban manufacturing system characteristic of a mineral economy.

Steam engines were complex technologies and boosters engaged in significant experimentation to adapt their boilers to anthracite coal as a fuel source. For example, the low flame of an anthracite fire required engineers to place the boiler closer to the heat source. The first reported successful use of anthracite in a steam engine in the United States occurred in 1825 at the Phoenix Nail Works of Jonah and George Thompson on French Creek in Chester County, Pennsylvania.⁸⁵

⁸⁴ On the history of the Lowell mills, see: John F. Kasson, *Civilizing the Machine: Technology and Republican Values in America, 1776-1900* (New York: Grossman Publishers, 1976), chapter 2; Thomas Dublin, "Women, Work, and Protest in the Early Lowell Mills: 'the Oppressing Hand of Avarice Would Enslave Us'," *Labor History* 16 (1975).

⁸⁵ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 50.

Philadelphia soon took a leading position in the use of steam engines. In 1831, it was reported that there were between sixty and eighty steam engines in Philadelphia burning anthracite, with more operating in New York City and on steamboats.⁸⁶ According to trade journals, nearly all of the steam engines in Philadelphia were fueled with anthracite.⁸⁷ By 1838, Philadelphia County led the nation in the use of steam engines and the various applications to which they were applied. According to a report prepared by the Treasury Secretary Levi Woodbury, 178 of the nation's 1,860 stationary steam engines were in Philadelphia and another 41 were in use in the surrounding counties, representing more than 10 percent of the nation's capacity.⁸⁸

These steam engines did not represent a very sizable fraction of the overall anthracite consumption. Most of the stationary steam engines were of relatively small capacity (5-20 horsepower) especially when compared to steam vessels, which often had engines rated at more than 100 horsepower.⁸⁹ Attack et al estimate that average fuel consumption for a steam engine in the 1830s was 7.5 pounds of fuel per horsepower hour.⁹⁰ According to Woodbury's report, Philadelphia's 178 steam engines were rated at a total of 1860 horsepower. Assuming they were operated 6 days a week for 12 hours a day, this gives a total coal demand in 1838 of about 26,000 tons.⁹¹ Given that there were only 87 steam engines reported in New York State and 32 in New Jersey according to the report, it is unlikely that the total fuel demand in stationary steam engines was more than

⁸⁶ "Anthracite Coal Trade of the United States," *Hazard's Register*, July 16, 1831.

⁸⁷ "To the Editor of the NY Post," *Miners' Journal*, February 5, 1831.

⁸⁸ Secretary of the Treasury, *Report on Steam Engines*, 156-167, 379.

⁸⁹ The relatively small size of steam engines was linked to the pattern of small to medium sized enterprises which dominated Philadelphia's industrial landscape.

⁹⁰ Attack, Bateman, and Weiss, "The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing," 295.

⁹¹ The math is as follows: (7.5 pounds of fuel x 1860 horsepower x 12 hours per day x 309 days per year) / (2000 pounds per ton) = 25,863 tons of coal used in steam engines.

40,000 tons at this date.⁹² As total anthracite shipments in 1838 were more than 700,000 tons, less than 6 percent of total anthracite consumption went towards stationary steam engines. By the end of this period, stationary steam engines consumed much larger quantities of anthracite. There is no reliable data on steam engines from 1850 and 1860, but by 1870, it was reported that there were 1,877 establishments using steam power in Philadelphia with a total capacity of 49,674 hp, thereby requiring approximately 275,000 tons of coal per year.⁹³

The use of steam engines in manufacturing contributed to two of the shifts of the mineral economy. The first was the exponential increase in energy consumption, shown by the large increase in steam engines and coal demand. The second shift was geographic. By providing a flexible form of power, steam engines gave energy-intensive enterprise the option to locate a plant in an urban location where workers, suppliers, and markets were nearby. Several industries, particularly textile and metal manufacturers in Philadelphia, took advantage of these opportunities and concentrated in cities. Similar to the ways that canals supported numerous iron forges along their banks, steam engines allowed a dense concentration of manufacturing enterprises in urban locations. Instead of moving manufacturing establishments and workers to sites of energy, entrepreneurs built factories in cities where workers and supplies were abundant. In other words, the Philadelphia model replaced the Lowell model as the primary pattern of American industrial development. Despite the persistent popular mythology of the small New

⁹² Secretary of the Treasury, *Report on Steam Engines*, 379.

⁹³ Philadelphia Committee on United States Census 1870, *Manufactures of the City of Philadelphia. Census of 1870* (Philadelphia: King & Baird, 1872), 27. By the 1890s, Attack, Bateman, and Weiss argue fuel consumption of steam engines had declined to two pounds per horsepower-hour. In 1870, it was most likely around 3 pounds. If the engines operated 12 hours a day, 6 days a week, the fuel consumption would be 278,969 tons (6 x 12 x 52 x (3/2000) x 49,674). Attack, Bateman, and Weiss, "The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing," 295.

England mill town tucked into nature, by mid-century “the dominant patterns of industrializing ... America would come to resemble ... Pennsylvania much more than the model mill towns of New England.”⁹⁴

Steam Engines in Coal Mining

Beginning in the 1830s, steam engines began to play an important role in the mining of anthracite coal. As coal miners began to dig deeper for coal, they found that mines began to fill with water. In addition, deep shafts required powerful fans to provide ventilation. By the 1830s, most mine operators found that steam engines were necessary to handle the increasing quantities of water. In the early 1840s, steam engines were also applied to coal-breaking, the process of smashing large chunks of coal into pieces that consumers could easily use.

The growth of steam engines used in mining is documented most clearly in the Schuylkill region. The North American Coal Company purchased the first steam engine used for coal mining in 1833; by 1840, there were twelve engines in the Schuylkill region. A decade later, there were 165 steam engines, and the rate increased steadily. To estimate the total fuel consumption of these engines, it must be kept in mind that they were likely far less efficient in operation than those in Philadelphia since the coal supply was essentially free (mining operators used leftover coal bits that could not be sold in markets) giving the companies little incentive to economize.⁹⁵ I estimate the total coal

⁹⁴ D. W. Meinig, *The Shaping of America: A Geographical Perspective on 500 Years of History*, 4 vols. (New Haven: Yale University Press, 1986), Volume 2, Continental America, 1800-1867, p. 397.

⁹⁵ To illustrate this, a report on the North American Coal Company's 15 horsepower steam engine in 1834 noted that it burned 2 tons of coal operating five hours a day. This implies that the engine was consuming fuel at the astounding rate of 53 pounds per horsepower-hour. Given that this was one of the first engines

consumption of these engines in Table 2.12 based on the assumption that they were in operation 16 hours a day, 6 days a week, and were less fuel-efficient than engines outside of the coal regions. It should be noted that this coal is not represented in the shipments of anthracite to markets calculated above since it was never shipped or sold.

Table 2.12: Steam Engines in Mining Operations, Schuylkill County, 1840-1865⁹⁶

Year	Engines in mining	Horsepower	Pounds of coal per horse-power hour	Coal consumption (in tons)
1840	12	364	9	8,000
1845	41	1,278	9	29,000
1850	165	4,753	8	90,000
1855	280	9,649	8	193,000
1860			7	
1865	320	18,500	7	325,000

This data can be extrapolated to the rest of the coal regions by estimating the percentage of output from the Schuylkill regions to the total anthracite output as seen in Table 2.13.⁹⁷

in mining operations, I assume that the efficiency was significantly higher in 1840, but also that the engines operated longer hours. "Anthracite for Steam Engines," *Hazard's Register*, Aug 30, 1834.

⁹⁶ Sources for Table 2.12: *Eighth Annual Report Made by the Board of Trade to the Coal Mining Association of Schuylkill County*, (Pottsville, PA: Benjamin Bannan, 1840); *Thirteenth Annual Report, Made by the Board of Trade, to the Coal Mining Association of Schuylkill County*; "Steam Engines in This Region," *Miners' Journal*, January 5, 1850; "The Coal Trade of 1855."; Daddow and Bannan, *Coal, Iron, and Oil, or, the Practical American Miner: A Plain and Popular Work on Our Mines and Mineral Resources, and a Text-Book or Guide to Their Economical Development*, 726. Pounds per horse-power hour is taken from the average efficiency rating of steam engines during this period as determined by Attack et al and assuming the engines were one-third less efficient due to the low incentives for coal efficiency Attack, Bateman, and Weiss, "The Regional Diffusion and Adoption of the Steam Engine in American Manufacturing," 295. This estimate is confirmed by contemporary reports which note that steam engines in the collieries in 1865 rarely achieved an efficiency better than six pounds of coal per horsepower hour. Total consumption is determined by assuming these engines were in operation 16 hours a day, 6 days a week.

⁹⁷ These estimates are similar to calculations made by Schaefer on coal consumption in the industry's steam engines. He estimates slightly higher overall consumption based on steam engines operating 24 hours a day, 6 days a week. Given that machines broke down and mines occasionally closed during slack seasons, I believe the average of 16 hours a day is a more reasonable measure over time. Donald Fred Schaefer, *A Quantitative Description and Analysis of the Growth of the Pennsylvania Anthracite Coal Industry, 1820 to 1865* (New York: Arno Press, 1977), 207.

Table 2.13: Steam Engines in Mining Operations, Anthracite Regions, 1840-1865⁹⁸

Year	Schuylkill coal shipments (% of total)	Coal consumption in Schuylkill steam engines	Shipments from other regions (% of total)	Coal consumption in other region steam engines	Total consumption in steam engines
1840	52	8,000	48	7,500	15,500
1845	54	29,000	46	25,000	54,000
1850	52	90,000	48	85,000	175,000
1855	51	193,000	49	190,000	383,000
1860	40		60		
1865	43	325,000	57	430,000	755,000

The use of anthracite to mine anthracite eventually brought the coal regions into the mineral economy by substituting coal for organic energy sources. However, what is perhaps most notable about the process of coal mining is the extent to which its activities, while fundamental to the mineral economy, were mostly characteristic of the organic economy. For many years, the anthracite industry used picks, wagons, mules, and human muscles for its energy then shipped its products along canals. While steam engines assisted these efforts, anthracite mining was not as intensively mechanized as many other aspects of industrial manufacturing. Therefore, coal mining was a curious hybrid between organic and mineral economies.

Steam Engines in Transportation

Steam engines could also provide motive power when connected to paddles and wheels. Anthracite boosters found great success in encouraging steam vessels to run on coal, but had much greater difficulty with railroads. Even the Reading Railroad, which carried large amounts of anthracite, burned wood in its locomotives for many years.

⁹⁸ Sources for Table 2.13: Schuylkill percentage of total shipments is determined by taking the ratio of Schuylkill shipments to all anthracite shipments. Coal consumption in Schuylkill region is from Table 2.12. Shipments from other regions is the remainder from Schuylkill shipments. Coal consumption in other region mining is determined by taking the ratio of output to coal consumption in steam engines in the Schuylkill region to the other regions: Schuylkill coal consumption divided by the % of total output minus Schuylkill coal consumption.

Steam vessels involved in the coastal trade surrounding New York and Philadelphia consumed the greatest amount of anthracite for transportation-related ventures.⁹⁹ Americans were pioneers in the adoption of steam power for river transportation, beginning with Robert Fulton's *Clermont* in 1807. Early steam vessels burned wood, which was initially abundant along the paths of the boats (mostly the Delaware and Hudson rivers, and the Atlantic coast). However, the steamboats' massive appetites for fuel soon reduced supplies of timber. In 1828, it was reported that the New York City fleet of steamers consumed 200,000 cords of pine per year and that Philadelphia's fleet used an additional 150,000 cords. Most of the fuel wood came from New Jersey, though some was imported from North Carolina.¹⁰⁰ As early as 1829, the pine lands of New Jersey, previously considered of low value, were being rapidly deforested for use in steam vessels and charcoal production.¹⁰¹ Steam vessels in the 1840s continued to consume large quantities of wood when it was available: "[s]mall and medium-sized river steamboats burned from twelve to twenty-four cords of wood a day, and the large boats consumed as much as fifty to seventy-five cords for every twenty-four hours running time."¹⁰² While the pressures to find a new fuel source were less significant along the sparsely populated Mississippi River, the deforestation along commonly traveled routes in the American mid-Atlantic and northeast made the fuel shortage more acute.

⁹⁹ There was also a significant development of steamboats along the Ohio and Mississippi rivers, in what was then America's west. These boats used wood and bituminous coal from the Pittsburgh coalfields for fuel.

¹⁰⁰ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 91.

¹⁰¹ "Pine Lands of New Jersey," *Hazard's Register*, July 25, 1829.

¹⁰² Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 86.

The coal transport companies saw the potential for a large market and took important steps in solving the technical problems associated with adapting anthracite to steam vessels. The Lehigh Coal and Navigation Company made the first efforts beginning in 1826.¹⁰³ By 1831, their steam ship, *The Pennsylvania*, was towing coal barges up and down the Delaware River using anthracite for fuel. It required three tons of coal transport coal barges weighing 400 tons 66 miles.¹⁰⁴ The company would build a few other steam vessels running on anthracite to haul its coal. In addition, the Delaware & Hudson Company dedicated great effort to introducing anthracite into steam vessels. The company believed that the particular characteristics of Lackawanna coal (which was lighter than Schuylkill or Lehigh coal and therefore easier to ignite) gave it an advantage for producing steam. In addition, steam navigation was of great importance to the commerce of New York City, which consumed most of the coal from the Delaware & Hudson's mines. The company absorbed the costs of converting fireboxes and grates in New York City ferries, gave free anthracite to steam vessels experimenting with its use, and supported efforts by entrepreneurs to develop marine boilers designed for anthracite.¹⁰⁵

The extensive use of anthracite coal in steam vessels really began at the beginning of the 1840s. In 1831, the Delaware & Hudson Company reported that only six steam vessels in operation in the New York City area used anthracite.¹⁰⁶ However, by 1839, the LC&NC could report to its stockholders that many boats on the Delaware, Hudson, and

¹⁰³ As discussed in the previous chapter, Josiah White's plan for the Delaware Division canal, submitted in the 1820s, already called for locks large enough to enable steam vessels to travel all the way to Mauch Chunk.

¹⁰⁴ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 90.

¹⁰⁵ Ibid., 92-93.

¹⁰⁶ Ibid., 92.

Long Island Sound were using anthracite.¹⁰⁷ In 1845, the Coal Mining Association of Schuylkill County estimated that there were 35 steam boats based in Philadelphia that used 45,000 tons of anthracite and that the steam vessels based in New York “consume annually more than 100,000 tons of Anthracite coal, making the whole amount at these two points not less than from 150 to 160,000 tons consumed annually, for generating steam for the propulsion of vessels.”¹⁰⁸ An article from *LeBow’s Review* noted that in the 1850s, over half the steamships in the American coastal trade burned anthracite, consuming around 250,000 tons annually.¹⁰⁹ The U.S. Navy took note of these developments and determined that anthracite coal provided 66 percent more power compared with bituminous, leading the Engineer-in-Chief to recommend the use of anthracite.¹¹⁰

Although there was substantial effort put into developing ocean-going steam vessels that burned anthracite, this market never developed. Despite many promotional articles and the construction of a few examples, the use of anthracite in steam vessels was largely limited to mid-Atlantic rivers and the trade of the eastern seaboard.¹¹¹ The regional supply of anthracite coal was one of its limitations for international trade.

¹⁰⁷ Ibid., 90.

¹⁰⁸ *Thirteenth Annual Report, Made by the Board of Trade, to the Coal Mining Association of Schuylkill County*, 8-9.

¹⁰⁹ *LeBow’s Review*, as cited in Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 104-5.

¹¹⁰ Secretary of the Navy, “In Compliance with a Resolution of the Senate, a Report of the Engineer-in-Chief of the Navy, on the Comparative Value of Anthracite and Bituminous Coals,” (Washington, DC: 1852), 5. It does not appear this recommendation was followed, mostly because the supply of anthracite was most prominent in the mid-Atlantic. If Navy ships were elsewhere, some feared that finding fuel sources would be difficult.

¹¹¹ There was substantial effort from boosters to develop this trade, even going as far to argue that anthracite was preferable to bituminous for ocean vessels because its white smoke dissipated quickly, thereby rendering the ships less prone to attack by pirates: “Anthracite Coal,” *Miners’ Journal*, Oct 23, 1841.

Bituminous coal was much more broadly available at international ports than anthracite coal, making it a safer investment for ship captains.

The other great transportation revolution of the antebellum era was the railroad. Boosters had high hopes for the use of anthracite in railroad locomotives, but this market did not develop as they hoped. This was a surprising result to many, especially since one of the first successful American locomotives, the “Tom Thumb” of the Baltimore & Ohio Railroad in 1832, burned anthracite.¹¹² However, when used in locomotive engines, the intense heat of anthracite melted grates, developed clinkers that impeded combustion, and destroyed boilers. In addition, it was harder to control the flame of an anthracite fire to increase or decrease the power output when the train was starting, stopping, or going up slopes. The higher maintenance costs associated with burning anthracite encouraged the Baltimore & Ohio and other railroads to use other fuel sources (mostly wood).¹¹³

The Reading Railroad’s difficulties exemplify the challenges and frustrated expectations of using anthracite in the iron horse. It was shocking to many that when the Reading Railroad first began carrying coal in 1841, its engines burned wood, which was more costly and occupied more space than anthracite. It was not until the early 1850s that the Reading finally adopted anthracite widely for its fleet. In 1855, G. A. Nicolls, the Engineer and Superintendent of the Reading Railroad, wrote an open letter in which he described the efforts of the Reading to burn anthracite in its engines. He noted that as of 1847, only 5 percent of their engines used anthracite before an intense effort to convert

¹¹² Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 111. Three years earlier, the *Stourbridge Lion*, the first locomotive engine brought to the United States by the Delaware & Hudson Canal Company, also burned anthracite. However, the engine was too heavy for its tracks and only made a single journey. Hudson Coal Company, *The Story of Anthracite*, 90.

¹¹³ “Coke and Anthracite for Locomotives,” *Miners’ Journal*, May 25, 1850.

to coal. By 1854, 85 percent of their engines used anthracite and the company's locomotives burnt 50,000 tons of anthracite per year. Each roundtrip between Pottsville and Philadelphia consumed 8 or 9 tons of anthracite (with a 740 ton loaded train outbound and a 250 ton empty train returning traveling at 10 to 12 miles per hour). However, the use of anthracite meant that the boilers had to be replaced every six months, three times as often as wood-fired boilers, thereby leading to maintenance costs that were about 10-20 percent higher.¹¹⁴

By 1855, then, many of the problems associated with using anthracite in locomotives had been addressed reasonably effectively. Some of the other railroads in the anthracite region, such as the Beaver Meadow Railroad, had used anthracite in their engines before this time, but the scale of their operations was much smaller than the Reading's.¹¹⁵ After the Civil War, most of the railroads in the anthracite region were using anthracite coal, but railroads in other parts of the United States largely relied on bituminous coal from other locations. In the end, the vast majority of the coal consumption on the nation's railroads was not anthracite.

However, anthracite did play an important secondary role in spurring the growth of the railroad system. Building railroads required huge quantities of iron and steel mostly for tracks, but also for locomotives and railroad cars. Much of this iron and steel was forged with anthracite. As shown previously, the anthracite iron industry made it easier and cheaper to construct railroad systems by increasing the supply of iron and

¹¹⁴ G. A. Nicolls, "Anthracite Coal in Locomotives," *Miners' Journal*, Jan 27, 1855.

¹¹⁵ John Nathan Hoffman, *Anthracite in the Lehigh Region of Pennsylvania, 1820-45* (Washington: Smithsonian Institution Press 1968), 112.

lowering its costs. Therefore, even if locomotives were powered by another fuel source, they had likely been crafted out of iron and rode on rails forged with anthracite.

Coal-powered steam engines on ships and railroads altered traditional relationships between land and transport. Waterways were the main transport conduits of the organic economy. Before the introduction of steam vessels, there were already several sailboats plying the coastal waters of the Atlantic seaboard and the interior rivers. In this sense, steam vessels simply enhanced existing patterns, making transportation faster and more reliable. However, the ability of steam vessels to travel upriver against the current opened new trade patterns that were not possible in an organic economy. For example, traveling up the Hudson River to Albany in a sailboat was difficult, time-consuming, and expensive, taking as long as nine days.¹¹⁶ Most of the trade, such as bulk agricultural goods, only floated downriver in barges. The upriver transportation costs could only be recouped on high-value goods, such as mail, manufactured products, and passengers. Steam vessels changed this logic, significantly lowering the cost for upriver transportation and thereby enabling new patterns of reciprocal trade that were not possible before.

Anthracite coal also supported the extension of steam vessel operations. The organic economy fueled the beginnings of the steam vessel trade, but by the 1830s it was already reported that the main trade routes of the mid-Atlantic were being deforested. The conversion to anthracite coal as fuel ensured that lack of wood would not hamper trade along the eastern seaboard.

¹¹⁶ Binder, *Coal Age Empire: Pennsylvania Coal and Its Utilization to 1860*, 96.

Steam engines had their most revolutionary effects on transportation with railroads, which enabled a significant shift of trade away from waterways and allowed the development of regions lacking navigable rivers. However, because of its extensive waterways, in addition to its well-developed canal network, railroads were not as important to the growth and expansion of the mid-Atlantic as they were to other regions in the United States.¹¹⁷ In the end, anthracite coal's most important stimulus to the rise of railroads came through enabling the production of cheap and abundant iron.

Factories

The fourth broad category of anthracite consumption came from its use in heat-intensive enterprises. In addition to powering steam engines, anthracite also provided direct heat for a wide variety of businesses that had previously relied on wood, charcoal, and imported bituminous coal. Bakers, brewers, distillers, brick-makers, sugar refiners, tanners, bleachers, salt-makers, metal-workers, and more all required significant amounts of heat to make a finished product. In fact, very few business enterprises did not require a form of heat, if only to warm the working environment during the winter. Even hat makers began adopting anthracite to heat the pots of water necessary for shaping materials.¹¹⁸

For enterprises simply needing heat, substituting anthracite for wood or imported bituminous coal was a relatively straightforward process. There were a few kinks to be worked out, such as reconfiguring stoves to burn anthracite, modifying boilers to

¹¹⁷ Railroads were particularly important for developing the American West, as there were fewer navigable rivers to facilitate development. For a remarkable account of the importance of railroads to Chicago and its hinterlands, see: Cronon, *Nature's Metropolis: Chicago and the Great West*.

¹¹⁸ "Anthracite Coal."

withstand the heat of an anthracite fire, and separating the gas emissions from edible goods to ensure they did not taste of sulfur or soot. However, in comparison with the efforts required to apply anthracite to steam engines or iron manufacture, these challenges were minor. As anthracite was the cheapest heating fuel available by the 1830s, it is likely that most manufactories in Philadelphia and New York converted to coal for their heating needs.

The decentralized nature of these businesses and the lack of statistics make it impossible to estimate the total use of coal in this category. However, factories used enough anthracite to make a notable difference in Philadelphia's economic development. Diane Lindstrom noted that whereas abundant water power in New England encouraged the growth of textile mills focused on spinning and weaving, Philadelphia manufactures took a leading role in heat-intensive operations, including bleaching, dyeing, paper making, glass making, distilling, and metal-working.¹¹⁹ As with steam engines, the use of coal in urban factories helped create a new geographical pattern of production and consumption centered in cities.

The use of anthracite coal in factories shaped the mineral economy in a manner similar to its use in home heating. At first, the conversion to anthracite was simply a substitution of one fuel source for another. Over time, however, the fact that anthracite coal consumption could be expanded exponentially and concentrated in a single place created a new set of relationships between land and energy consumption. Shipments of anthracite coal transformed cities from energy-scarce places in organic economies into sites of superabundance capable of supporting dense concentrations of people and

¹¹⁹ Lindstrom, *Economic Development in the Philadelphia Region, 1810-1850*, 48, footnote 101.

factories. Simply put, without abundant energy from anthracite, it would have been impossible for Philadelphia to become “the workshop of the world.”

Conclusions

Winners and Losers

The benefits of the mineral economy were not evenly distributed across the mid-Atlantic. Instead, the energy landscape of anthracite coal structured who had access to cheap energy, thereby influencing where it was used and its regional effects. Where people lived in relationship to the canal network—at the terminus in Philadelphia or New York, at the beginning in the anthracite regions, along the route, or not connected at all—structured their experience of the emerging mineral economy. The most significant changes were felt in cities at the ends of canals followed by the coal regions and towns along the canal paths. The lives of those in the countryside were minimally affected by these changes.

The shift from an organic to a mineral economy was most pronounced at the termini of the transport networks in Philadelphia and New York. Residents of these cities consumed the greatest amounts of coal in the widest array of uses and most quickly adopted the characteristics of a mineral economy.¹²⁰ Seaboard cities led the region in the use of coal in home heating, steam engines, and factories—all the categories of consumption except iron production. By 1860, the large majority of Philadelphians and New Yorkers were burning anthracite in their homes and the cities’ heat-intensive

¹²⁰ Other seaboard cities including Boston, Baltimore, Providence, and New Haven also experienced some of the changes characteristic of a mineral economy during this period when coal was shipped along the Atlantic seaboard from Philadelphia and New York.

businesses relied on coal. Most of the steamboats burning anthracite were headquartered in these cities as well. In addition, while Philadelphia was not a center of iron production, the Quaker City supported a significant industry processing iron into finished products. Overall, Philadelphia and New York had clearly developed new relationships with land, energy, and limits that were no longer characteristic of an organic economy.

The story in the anthracite regions was somewhat different. There were sweeping social changes for residents of towns such as Pottsville, Mauch Chunk, and Honesdale due to the rise of the coal industry, the rapid influx of population, and the booms and busts associated with mining districts. However, these changes were not specific to the development of a mineral economy. In fact, much of the activity in the anthracite regions was characteristic of the organic economy. The main tools of coal mining were pickaxes, wheelbarrows, wagons, donkeys, and canals. Most people not involved in the coal industry farmed. It is interesting to note that although the anthracite regions were supplying the raw material that would make the mineral economy possible, the production of coal occurred largely in the context of the organic economy.

It was only with the extensive use of steam engines for coal mining during the 1840s and 1850s that the anthracite regions began to operate as a mineral economy. As the industry matured and the coal above the water level had been mined, the expansion of the industry was dependent upon solving the problems of draining deep shafts, raising the coal hundreds of feet, and providing proper ventilation. Because of the amount of power involved, traditional power sources such as animals could not address this problem on a

large scale.¹²¹ Steam engines, which were originally developed for this capacity in Britain, provided an effective solution. With the large-scale introduction of steam engines for mining, and later for railroads, anthracite mining took on the patterns of the mineral economy.

At the beginning of the period, the regions along the paths of the canals experienced less change than either the coal regions or the cities. Between 1820 and 1840 only around 5 to 10 percent of the coal shipped on the Schuylkill and Lehigh canals was consumed before reaching tidewater.¹²² Even comparatively large towns along the paths, such as Reading, only had 8,410 people in 1840. Wood was still relatively abundant for heating and manufacturing purposes, and the limits of the organic economy were hardly constraining to people in these towns due to their small populations. The development of the anthracite iron industry in 1840 initiated a significant change. As discussed previously, the production of iron with anthracite coal was characteristic of a mineral economy. For people living in towns such as Reading, Phoenixville, Bethlehem, and Allentown, the anthracite iron industry ushered in a significant change to their local economies. The iron industry generated significant amounts of wealth for several decades and encouraged the growth of subsidiary industries. However, because there was relatively little consumption of coal separate from the iron industry, the rhythms and patterns of the organic economy persisted in most places outside the great iron works.

In the rest of the mid-Atlantic, there was very little experience of the mineral economy. The predominantly rural population experienced little change in their daily

¹²¹ Land was once again a limiting constraint. Draught animals required significant land area for grazing and for raising other food stock. This limited the possible number of animals that could be supported in the coal regions.

¹²² See data tables earlier in the chapter.

lives from the development of coal canals and anthracite consumption. Their patterns were still governed by the organic economy, although the limits were hardly apparent and rarely mattered in a region where forests were still abundant. The charcoal iron industry continued to increase its output in rural Pennsylvania, taking advantage of the uncut forests. Farming communities could find plenty of streams to support mills and congregated along waterways that provided water power and transport opportunities to distant markets. On the whole, rural residents of the mid-Atlantic remained in the organic economy during the antebellum era.

Thus, the experience of these changes was significantly influenced by where people lived in relation to the paths of the anthracite canals. Moreover, these geographic shifts were not neutral. Economically, environmentally, and physically, the distribution of costs and benefits accompanying the development of the mineral economy favored those living in cities versus those living in the anthracite regions.

Economically, the development of the anthracite industry benefited cities the most. In Diane Lindstrom's analysis of the relationships between Philadelphia and its hinterland, she notes that while all regions may have benefited from the development of an integrated economy, the urban core experienced the greatest gains. She demonstrates that Philadelphia had the fastest rates of population growth, the highest rates of return on investment, and captured the greatest benefits of the transportation savings, which were usually passed on to consumers instead of producers.¹²³ In addition, the varied uses of coal in cities gave rise to a diversified urban economy that was better able to withstand peaks and valleys in business cycles. The dependence on a single product in the

¹²³ Lindstrom, *Economic Development in the Philadelphia Region, 1810-1850*, chapter 6.

anthracite regions (coal) and canal towns (iron) left them subject to significant recessions when the coal and iron markets experienced difficulty, a regular occurrence throughout the nineteenth century.¹²⁴

People in the anthracite regions bore most of the negative environmental impacts of the anthracite industry. Coal mining often produced scarred landscapes. In addition, it produced large quantities of coal dust that settled on houses and fields, tainted drinking water supplies, and caused “black lung.” While most anthracite was burnt in urban locations, its high carbon content mitigated the effects of smoke pollution. Anthracite smoke was far cleaner than bituminous smoke due to the lack of impurities in the coal. Therefore, the urban air quality of eastern seaboard cities such as Philadelphia and New York, while never ideal, was far better than in urban locations dependent on bituminous coal like Pittsburgh, Chicago, and St. Louis.

Finally, coal mining in the antebellum era was an extremely dangerous occupation. Miners faced a range of physical threats including suffocation through poor ventilation, the collapse of mine shafts or tunnel supports, dynamite explosions, and fires. Anthony Wallace calculated that anthracite miners had less than an even chance of surviving fourteen years of employment without a fatal or crippling accident.¹²⁵ Workers in cities also experienced physical risks accompanying the rise of industrialization and steam engines, but not to the extent that permeated coal mining. Therefore, those living

¹²⁴ The anthracite and iron industries faced decline, as did all businesses, during such episodes as the Panic of 1837, the general slow trade of the 1840s, and the depression in 1857. Anthracite iron manufacturers also experienced hard times when the United States temporarily removed its protective barriers on iron in the late 1840s.

¹²⁵ Anthony Wallace, “The Perception of Risk in Nineteenth Century Anthracite Mining Operations,” *Proceedings of the American Philosophical Society* 127, no. 2 (1983): 99.

in the anthracite regions experienced a disproportionate share of the costs of the anthracite industry while recouping fewer of the benefits than those living in cities.

Building Dependence

The mid-Atlantic's first steps into the mineral economy would not be its last. By the dawn of the Civil War, the mid-Atlantic had already become dependent on fossil fuel energy. At first, people experienced the new availability of anthracite coal as an open choice. A family could decide whether or not to purchase a coal-burning stove. A manufacturer could decide whether to use wood or coal for his heat and where to locate his factory. By 1860, this was no longer the case. Without ever-increasing supplies of anthracite coal, eastern seaboard cities would have struggled to heat their growing populations, the iron industry would have collapsed, transport networks would have failed, and there would have been an exodus of industries and people from urban centers. Residents of the mid-Atlantic had stepped into a brave new world of fossil fuel consumption from which they could only turn away with great difficulty. The free choices that people experienced about whether to use coal in the 1820s and 1830s were no longer free in 1860. Anthracite was a necessary part of life for people in the mid-Atlantic.

Two analytical concepts can help us make sense of this transition. In the history of technology, Thomas Hughes introduced the concept of momentum to describe an important characteristic of technological systems.¹²⁶ At the beginning of their development, technological systems are open to significant modification by social actors.

¹²⁶ Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*.

Over time, however, this flexibility is diminished as the system becomes more entrenched. This is partly economic—the capital investments in a system make it increasingly expensive to make any changes—and partly social—operators of the system establish stable rules and procedures and users become accustomed to a particular way of doing things. Likewise, in environmental history, Donald Worster has described the concept of an infrastructure trap.¹²⁷ Once a society commits a certain amount of resources to solving a problem in a particular way, those choices become a straitjacket, making it difficult to think about or address problems in any other way.

Fossil fuel consumption gained the momentum characteristic of an infrastructure trap in the mid-Atlantic during the antebellum era. Technologically, mid-Atlantic residents altered their built environment in ways that depended on the continued availability of anthracite. They constructed dense concentrations of homes and factories in cities that required more heat and power than organic sources could supply. Capitalists who invested in iron forges along the banks of the canals or operated steam vessels along the eastern seaboard could only generate a return to investors if ever-increasing quantities of coal were available. Moreover, as people gained familiarity with burning coal, they became accustomed to its use and benefits. The higher heating value of anthracite versus firewood and its lower cost meant that homes could be kept warmer in winter, factory production costs were lower, and land was freed up for other purposes. For most people with access to cheap and abundant anthracite, life was better with coal than without it.

The dependence of the mid-Atlantic on anthracite coal was partly generated by boosters and partly the product of thousands of individual decisions. Boosters and

¹²⁷ Donald Worster, *Under Western Skies: Nature and History in the American West* (New York; Oxford: Oxford University Press, 1992), chapter 4.

transport companies actively encouraged people to adopt anthracite and worked to create large and growing markets. However, boosters were not all powerful. It took thousands of individual choices by people and industrialists about where to live, how to heat their homes, and where to locate factories to create a new built environment and set of cultural expectations in the mid-Atlantic. Of course, these individual decisions were not made in isolation. They were structured by an economic system that encouraged the pursuit of profit and an energy landscape that made anthracite coal cheap and abundant. These collective efforts, choices, expectations, and forces pushed the mid-Atlantic steadily down a development path that depended on ever-increasing supplies of fossil fuel energy.

A Region Transformed

By the outbreak of the Civil War, the mid-Atlantic was a very different place than it had been forty years before. The creation of a new energy landscape and the first stages of a mineral economy had altered many aspects of social life, including urbanization, industrialization, labor practices, regional diversification, immigration, and political debates about the future of the nation. While each of these processes were shaped and influenced by a wide variety of social, cultural, economic, and environmental factors, coal played an important role in each of them as well. This section reviews some of the broad regional changes impacted by the emerging mineral economy.

Urbanization and industrialization were synergistic processes, both of which were enabled and amplified by fossil fuel energy. Anthracite coal provided heat for people's living needs and energy for industrial operations, thereby making it both possible and

desirable for residents and businesses to congregate in cities. The dense concentration of energy, labor, markets, and technological skill in cities, in turn, sustained and encouraged the rise of an urban industrial economy.

Both urbanization and industrialization initiated broad sets of social changes in how mid-Atlantic residents lived, worked, and played. Life in cities was very different than in the countryside. For example, most farmers in the early nineteenth century grew many of the crops they needed for food and exchanged surplus goods on a barter system. Urbanites, by contrast, relied on a cash economy to purchase nearly all the necessities of life. Farmers lived and worked on the same property while urban workers resided and labored in separate spheres, commuting to and from factories and homes. The location of these residences, in turn, were increasingly balkanized along class and ethnic lines as cities like Philadelphia and New York grew to house hundreds of thousands of people.¹²⁸ This balkanization increased the visibility and experience of inequality in the city. Even though inequality was always part of American history—10 percent of Philadelphia's population in 1774 owned nearly 90 percent of the taxable wealth¹²⁹—the small size of the town brought people from all classes and backgrounds into regular interaction on the streets. By 1860, the spatial expansion and segmentation of cities made it much less likely that people of different racial, ethnic, and socio-economic backgrounds would cross paths.

Industrialization further amplified these changes. The shifts accompanying industrialization touched practically every aspect of social life, including the distribution

¹²⁸ Licht, *Industrializing America: The Nineteenth Century*, 66-67.

¹²⁹ Sam Bass Warner, *The Private City: Philadelphia in Three Periods of Its Growth* (Philadelphia: University of Pennsylvania Press, 1968), 9.

of wealth, the goods people used in home and at work, and the balance of power between regions. As summarized by Walter Licht, industrialization was linked to: “[t]he expansion of market activity, the spread of wage labor, mechanization, the coming of the factory system, the massive migration of people into and through the country, urbanization, occupational change, social segmentation and divisions within communities, labor organization, the emergence of a distinct middle class, the separation between men and women, declines in fertility, and ultimately, the rise of the large-scale corporation.”¹³⁰ Few aspects of daily life were left untouched by industrialization.

A closer look at labor practices shows the deep and varied effects of industrialization on workers. First, industrialization undercut the traditional system of artisan production and the apprenticeship system that had previously structured careers for laborers. Instead of being apprenticed to a master craftsman in a small shop, laborers were more likely to work in a larger factory with little training. The time-discipline of the factory schedule replaced the seasonal rhythms characteristic of craft production.¹³¹ Second, new machines altered the skills required to operate them. Some machines such as steam engines were complex technologies demanding a new class of highly skilled operators. The same machines could also create the need for unskilled labor such as feeding coal into boilers. Therefore, industrialization was linked to an increasing gap between skilled and unskilled labor. Finally, these changes in labor practices gave rise to new forms of worker protest. Workers gathered together in new organizations like the Working Men’s Party to demand higher wages, shorter working hours, protection from

¹³⁰ Licht, *Industrializing America: The Nineteenth Century*, 79.

¹³¹ Bruce Laurie, *Working People of Philadelphia, 1800-1850* (Philadelphia: Temple University Press, 1980), 13-14.

dangerous machinery, and other benefits. These early collective actions by laborers would shape the emergence of unionization in the following decades.¹³²

The social effects of urbanization and industrialization were structured by the energy landscape of anthracite coal. The primary points of delivery for coal were New York and Philadelphia, and it is therefore no surprise that these were the nation's largest cities by 1860 with 813,669 and 565,529 people, respectively. Baltimore, with access to coal via the Susquehanna River, was third with 212,148 residents while Boston, St. Louis, and Cincinnati all had more than 150,000 people.¹³³ Moreover, Philadelphia (99,003) and New York (102,969) had more workers engaged in manufacturing. Than any other American city.¹³⁴ In other words, just the industrial workers of New York and Philadelphia constituted a larger population than all the residents of almost any other American city at the time. In the words of Thomas Cochran, anthracite coal helped give rise to "one great manufacturing complex from Wilmington to New York. From 1843 to 1860 this megalopolis was probably the most rapidly growing large industrial area in the world."¹³⁵ Coal, canals, and the industrial cities they served grew together synergistically, but only in a limited geographic area.

The development of the mid-Atlantic's industrial economy heightened the divergent trajectories of various American regions in the antebellum era. By 1820, it had already been clear that New England, the mid-Atlantic, and the South were evolving along different economic trajectories for a variety of historical, cultural, and

¹³² Licht, *Industrializing America: The Nineteenth Century*, Chapter 3.

¹³³ Population statistics from: Andriot, *Population Abstract of the United States*.

¹³⁴ Meinig, *The Shaping of America: A Geographical Perspective on 500 Years of History*, Volume 2, p. 384.

¹³⁵ Cochran, *Frontiers of Change: Early Industrialism in America*, 112.

environmental reasons. The small farms and mill towns of New England operated differently than the large grain farms and artisan shops of the mid-Atlantic or the large plantation cash crop agriculture system of the South.¹³⁶

The introduction of fossil fuel energy exacerbated these differences, thereby playing an important role in the start and end of the Civil War. As described by John Majewski, Abraham Lincoln's observation of a "house divided" could be better understood as a house dividing over several decades.¹³⁷ Parts of Pennsylvania and Virginia that had similar climates, soil endowments, and population densities at the beginning of the century had grown apart over the next sixty years. These tensions spilled out into the political domain in battles between northern politicians seeking a stronger federal government and protective tariffs versus southern politicians advocating for lower taxes and greater states' rights. While these were not the central issues over which the Civil War was fought, the different economic trajectories of the regions contributed to the belief among many that secession made sense politically and economically.

Once the Civil War began, the fact that the industrial heartland of America was north of the Mason-Dixon line gave the Union a great strategic advantage in the conflict. The mid-Atlantic was able to supply the Union Army with armaments and deliver these quickly using its extensive network of railroads, canals, and steamboats. The particular geography of the anthracite coal energy landscape, therefore, both contributed to the onset of the Civil War and its resolution in favor of the North.

¹³⁶ Licht, *Industrializing America: The Nineteenth Century*, Chapter 1.

¹³⁷ Majewski, *A House Dividing: Economic Development in Pennsylvania and Virginia before the Civil War*.

Anthracite coal also influenced immigration patterns in the antebellum era.

First and most directly, coal influenced transportation choices. Many immigrants arrived in America on steam-powered vessels. Once they landed, they could travel along canal or railroad networks to reach their final destinations. Second, coal influenced who immigrated. Building and operating an industrial enterprise required skilled laborers. Mid-Atlantic firms recruited highly trained workers from Britain, Wales, and Germany to work in the region's factories. For these workers, the promise of wages two to three times the average in Europe along with a cheaper cost-of-living was ample incentive to immigrate.¹³⁸ Third, the mineral economy influenced where immigrants went. The growing industrial opportunities in Philadelphia and New York contributed to the rise of immigration into the mid-Atlantic states. Moreover, with ample coal available to support large urban populations and industrial enterprises requiring both skilled and unskilled laborers, many immigrants remained in cities as opposed to moving to the countryside.¹³⁹ In these ways, coal created new patterns of immigration in the mid-Atlantic.

Finally, the mining, transport, and consumption of anthracite coal contributed to the rise of corporate power in the young nation, an issue of broad political debate at the time.¹⁴⁰ For many Americans, corporations were a threat to republican values. A complex and malleable set of ideas and values, republicanism encouraged government actions that struck a balance between centralized authority and personal liberty. In contrast to those seeking a strong central state, republicans feared that giving too much

¹³⁸ Licht, *Industrializing America: The Nineteenth Century*, 68.

¹³⁹ Cochran, *Frontiers of Change: Early Industrialism in America*, 130-31.

¹⁴⁰ On the development of corporate power in Pennsylvania, see: Andrew M. Schocket, *Founding Corporate Power in Early National Philadelphia* (DeKalb: Northern Illinois University Press, 2007); John Majewski, "Toward a Social History of the Corporation: Shareholding in Pennsylvania, 1800-1840," in *The Economy of Early America: Historical Perspectives & New Directions*, ed. Cathy Matson (University Park, PA: Penn State University Press, 2006).

power to the government would lead to abuses of power and corruption. Republican fears extended to corporations as well, particularly when these organizations were granted special privileges such as permission to print banknotes or seize property by eminent domain. Political virtue, according to republicanism, was based in the disinterested decisions of self-sufficient citizens. Therefore, republicans sought to protect the position of small farmers and artisans in order to create a sound basis for a virtuous polity. The presidencies of Thomas Jefferson and Andrew Jackson were particularly strongly associated with a rise of republican sentiments.¹⁴¹

The nexus of coal and corporations challenged republican values. Canals and railroads, anthracite iron forges, many mining enterprises, and several urban factories were capital-intensive operations that often sought corporate privileges. While it was not inevitable that the corporate form would be used to exploit fossil fuels—many of Philadelphia’s small shops were managed as partnerships, even including the large-scale Baldwin locomotive works¹⁴²—the size and scale of coal-based enterprises encouraged their directors to pursue incorporation: “[s]team engines ... permitted large-scale manufacturing, which in turn fostered corporate development. There is thus a direct connection between coal, mass industry, and the rise of the bureaucratic corporation.”¹⁴³ These developments were not always welcomed. We can see the attacks on the corporate privileges of the Lehigh Coal & Navigation Company in the 1830s as part of republican fears over monopoly power.

¹⁴¹ On republicanism in the antebellum era, see: Majewski, *A House Dividing: Economic Development in Pennsylvania and Virginia before the Civil War*, Chapter 4; Daniel T. Rodgers, "Republicanism: The Career of a Concept," *Journal of American History* (1992).

¹⁴² One of the most characteristic features of Philadelphia’s industrialization was the proliferation of small industrial enterprises: Philip Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925* (Princeton, N.J.: Princeton University Press, 1997).

¹⁴³ Licht, *Industrializing America: The Nineteenth Century*, 110.

The interconnections between corporate power and the exploitation of coal resources forced people to grapple with the proper balance between individual enterprise and centralized authority. While these debates were never resolved at the level of ideas, the nexus between the anthracite industry and the mineral economy led to a de facto defeat for republicans. Despite negative public attention, the corporate charters of industrial operations were rarely rescinded, and if anything, they became more common over time. This contributed to a shift in how people understood republicanism. Whereas in the eighteenth century, many republicans held that the pursuit of economic opportunity was inherently corrupting, this view had softened by the nineteenth century. In reviewing attacks on railroad companies in Virginia and Pennsylvania, Majewski notes that there was “widespread consensus in favor of commercial expansion” but “conflict about its particulars.”¹⁴⁴ The chartering, utilization, and social responses to anthracite corporations therefore both reflected and shaped the evolution of republican ideals in American political discourse.

In sum, transporting and consuming anthracite coal was not simply about providing a source of heat or mechanical power. Fossil fuel energy altered structural possibilities that generated a brave new world of human activity. Anthracite coal did not determine the political and personal responses people made to the mineral economy, but it did force people to address new problems. Their choices reshaped the development of the mid-Atlantic and the history of the nation.

¹⁴⁴ Majewski, *A House Dividing: Economic Development in Pennsylvania and Virginia before the Civil War*, 109-10.

Anthracite coal gave mid-Atlantic residents their first tastes of fossil fuel energy. But coal was not the only fossil fuel buried beneath the region's soil. At the dawn of the Civil War, sensational news reports began to emanate from western Pennsylvania. Prospectors drilling into the earth had found large quantities of petroleum. Speculators jumped aboard coal-powered locomotives that sped across tracks of iron forged with anthracite. Capitalists sent agents and financial promises to Titusville. Thousands of people flocked west to join the rush for black gold. The region's appetite for fossil fuels had been whet by anthracite, but the hunger had not been sated. It is to the story of petroleum and its transport that we now turn.

Chapter 3: The Tide-Water Pipeline and the Transport of Pennsylvania Petroleum, 1860-1900

While Pennsylvania's vast coal resources provided mid-Atlantic residents with their first large doses of fossil fuels, the Keystone State's energy endowment was not limited to bituminous and anthracite. In 1859, Edwin Drake successfully drilled for petroleum in Titusville, a small town in western Pennsylvania, giving rise to America's first oil boom. Within a few years, a sleepy and sparsely inhabited region became the center of oil production, with profound social, economic, and environmental effects on western Pennsylvania as well as the rest of the mid-Atlantic.

There are striking similarities between the development of Pennsylvania's anthracite and petroleum industries. Both sets of fossil fuel resources were located in rural regions significantly removed from centers of population and consumption. Booms and busts, land speculation, and environmental degradation characterized the development of each region. Moreover, both places became known by their representative product: the petroleum-bearing parts of Western Pennsylvania were soon called the "Oil Regions." Finally, solving transport problems shaped the development of each industry.

There were differences as well, many of which resulted from the choices people made about transport infrastructure. After experiments with wagons, barges, and railroads, pipelines became the dominant technology for moving oil. Pipelines created a distinct geography of oil flow that funneled petroleum to a few urban centers. Moreover,

by dramatically lowering the cost of shipping oil, pipelines created an energy landscape that helped deepen and extend the mid-Atlantic's transition into a mineral economy.

This chapter studies the development of oil transport infrastructure in the mid-Atlantic. I begin by looking at the role of early oil transport technologies in bringing petroleum to market. I then examine the building of the Tide-Water pipeline, the world's first long-distance pipeline for the transport of oil. My last section explores the shift to pipelines as the dominant transport technology for petroleum. The next chapter will study the flow of oil along the pipeline networks and the social consequences of oil consumption patterns.

I focus on the Tide-Water pipeline in this chapter for two reasons. First, it was a path-breaking technology that shifted the way oil was transported. Second, its history highlights the critical intra-industry struggles that can shape the development of transport infrastructure. Simply put, pipelines did not emerge out of a vacuum or out of a simple effort to find the lowest cost way to move oil—they were weapons in a highly competitive industry. Understanding the contingencies of the Tide-Water pipeline provides us with insights into how and why energy transport infrastructure is built, whose interests it is designed to serve, and the various factors (law, geography, capital, and luck) that shape its development.

Oil Transport By Water and Rail

Transport has been one of the great challenges facing the petroleum industry since its founding days. This fact is based in the geography of oil. Almost all of the world's

petroleum reserves are located in areas substantially removed from the places where the oil is refined and consumed. Today, oil often travels thousands of miles from wells in the Middle East to South America, from the Niger delta to China, and from Alaska to the continental United States. Although the relevant distances were shorter in absolute terms during the first quarter-century of oil's production, the transport problems were no less thorny.

The modern oil industry began in earnest in 1859 when "Colonel" Edwin Drake led an effort to drill for oil in Western Pennsylvania.¹ For years, small amounts of oil had been collected along the length of the aptly named Oil Creek, where petroleum seeped to the surface. Native Americans and European settlers gathered petroleum by laying blankets on pools of oily water, wringing the liquid out, and then evaporating or boiling off the water. They sold most of this oil for use in patent medicines used to treat bruises, burns, and rheumatism.² The scale of these operations was very small. By the 1840s, several farmers along Oil Creek gathered two to twelve barrels a season, producing an amount sufficient to supply the apothecaries in Pittsburgh, Philadelphia, and New York.³

Drake and his financial backers had different plans. They knew that oil could be refined into a valuable illuminating liquid as well as other profitable by-products.⁴ But

¹ Edwin Drake was not a Colonel, but his eastern backers addressed their letters to him as "Colonel" Drake in an effort to increase his standing in western Pennsylvania: Daniel Yergin, *The Prize: The Epic Quest for Oil, Money, and Power* (New York: Simon & Schuster, 1991), 26.

² George H. Thurston, *Pittsburgh and Allegheny in the Centennial Year* (Pittsburgh: A. A. Anderson and Son, 1876), 202.

³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 13.

⁴ Before authorizing Drake's drilling expedition, the group (led by the lawyer George Bissell of New York City and the banker James Townsend of New Haven) contracted with the Yale chemistry professor Benjamin Silliman to analyze the properties of petroleum from western Pennsylvania. His report indicated that the oil would be effective for a wide range of products: Benjamin Silliman, *Report on the Rock Oil, or Petroleum, from Venango Co., Pennsylvania: With Special Reference to Its Use for Illumination and Other Purposes* (New Haven: J. H. Benham, 1855).

how to increase the yields of oil? The men got inspiration from the salt-drilling industry. Several salt wells had reportedly filled with briny oil when drilled to a certain depth. While such oil was considered a nuisance because it ruined the salt, Drake and others believed the technique of drilling might produce petroleum in large quantities.

They were right. On August 28th, 1859, Uncle Billy Smith, Drake's drill operator, discovered that they had struck oil. The news spread like wildfire, and what followed was a speculative boom in oil production that utterly transformed western Pennsylvania. Men flooded into the area, leases of land were sold for fantastic sums of money, and towns were erected practically overnight. The nation, it seemed, had "oil on the brain."⁵

It quickly became clear that shipping oil would not be an easy matter. The Oil Regions were located in a remote part of western Pennsylvania with few roads and no railroad connections. While merchants had shipped small amounts of oil for use in patent medicines before 1859, the volume of oil moved was so minimal that they had little incentive to invest in improved transport facilities. As oil production boomed in the wake of Drake's discovery, however, the storage and transport of oil became the primary bottlenecks. An estimated 8,500 barrels of oil were produced in 1859, while output skyrocketed to reach 650,000, 2,118,000, and 3,056,000 barrels in the next three years.⁶

⁵ Good general sources for the early history of the oil industry include: Ida M. Tarbell, *The History of the Standard Oil Company* (New York: McClure, Phillips & Co., 1904); Nevins, *Study in Power*; Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906"; Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*; Brian Black, *Petrolia: The Landscape of America's First Oil Boom* (Baltimore: Johns Hopkins University Press, 2000); Yergin, *The Prize: The Epic Quest for Oil, Money, and Power*; Henry Demarest Lloyd, *Wealth against Commonwealth* (Englewood Cliffs, N.J.: Prentice-Hall, 1963 [1894]).

⁶ A barrel of crude oil typically contains 42 gallons. A barrel of refined oil typically contains 50 gallons. Production numbers cited from: *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, (Oil City, Pa.: Derrick Publishing Company, 1898), 804-5.

A driller fortunate enough to strike a gushing well, however, would watch most of the oil pour away until he could obtain barrels or erect storage tanks. Often, producers dug large holes into the ground in a desperate effort to collect the petroleum. Despite the large numbers of wooden barrels imported into the region, they were almost always in short supply. The inadequacy of storage facilities led to thousands of barrels of oil seeping into soil, collecting in rivers, and catching fire throughout the region.⁷

Producers found transport to be as insufficient as storage. First, oilmen followed the patterns of earlier industries in the area. For several years, lumber had been floated down Oil Creek to the Allegheny River, where it continued its journey to Pittsburgh. However, Oil Creek was too shallow and irregular to transport bulky goods reliably. Lumber merchants used pond freshets to overcome this limitation. A pond freshet involved creating temporary dams to raise the water level behind the barrier. When the floodgates were opened, the lumber floated along the stretch of higher water that resulted.⁸ However, pond freshets were not a particularly reliable approach to river management. Whenever a pond freshet was scheduled, crowds would gather to witness the frequent wrecks and crashes that ensued.⁹

With the increase in oil production, pond freshets were operated as often as three times a week during the early 1860s. Oil was loaded onto shallow barges capable of carrying between 25 and 1,000 barrels.¹⁰ A single pond freshet might involve several hundred boats. However, this coordination often created dangerous conditions: a

⁷ Black, *Petrolia: The Landscape of America's First Oil Boom*.

⁸ This approach to river management was also used along the Lehigh and Schuylkill Rivers. The temporary dams provided a function similar to White's "bear-lock" gates as discussed in Chapter 1.

⁹ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 3.

¹⁰ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 163-8.

December 1862 disaster triggered by breaking ice destroyed half of a freshet carrying 350 boats and 60,000 barrels of oil and caused \$350,000 of property damage. In 1865, a fire sparked by a lantern spread to nearly a hundred boats and led to the loss of 8,000 barrels of oil.¹¹

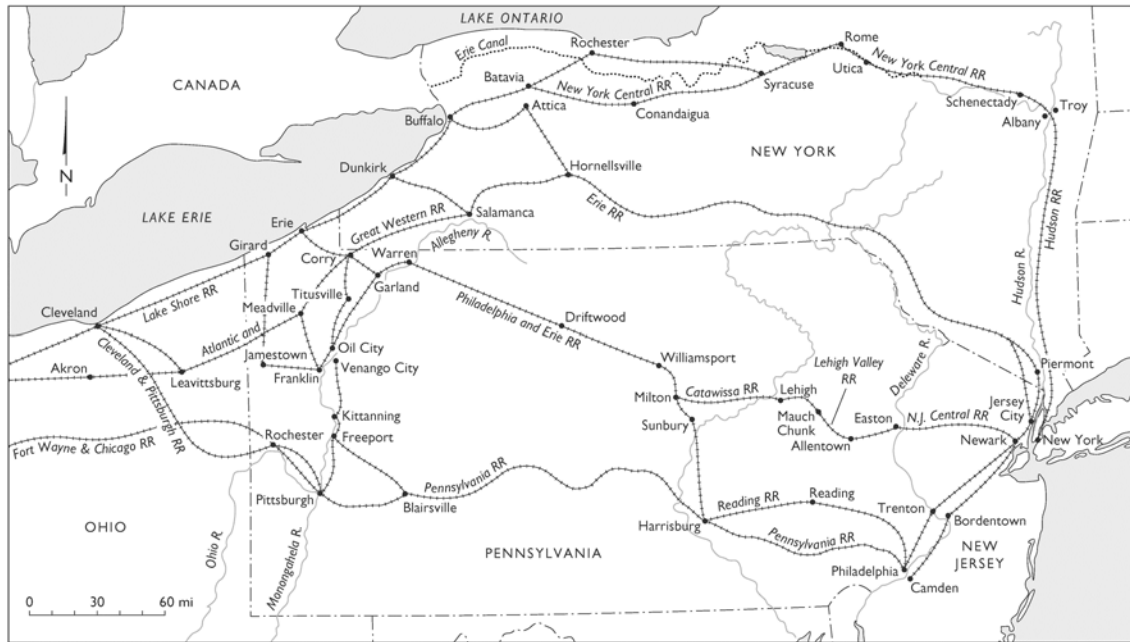
As the oil trade grew, railroad companies saw opportunities for profit and began expanding their tracks into the Oil Regions in the early 1860s. Local oilmen took the first steps to create railroad connections. Producers of oil seeking a better outlet for petroleum organized the Oil Creek Railroad in 1860. By 1862, they had completed a twenty mile line from Titusville to Corry, where the Sunbury & Erie Railroad had a connection. From Corry, oil could then be sent to Cleveland or the eastern seaboard via railroad, the Great Lakes, and the Erie Canal. In the following years, the Oil Creek Railroad was expanded further into the Oil Regions to capture more output. In 1864 the railroad shipped approximately 430,000 barrels of oil.¹² The creation of the Oil Creek Railroad drew other parties to the region as well. By 1862, the Atlantic & Great Western Railroad, working with the Erie Railroad, had extended its tracks to Corry to enter the oil business. Not wanting to be left out, the Pennsylvania Railroad contracted with the Philadelphia & Erie Railroad to extend its tracks to Sunbury, so that it would have access to the Oil Regions.¹³ This began an intense competition between the major trunk railroads that would play a significant role in the transport of oil.

¹¹ Ibid., 168.

¹² Ibid., 170.

¹³ Ibid., 170-175.

Map 3.1: Railroads in the Oil Regions, 1860s



While rivers and railroads helped get oil to distant urban markets, neither approach addressed local transport. Before it could be shipped long distances, oil had to get from the wellhead to a river shipping point or a railroad depot. When Pennsylvanians first struck oil, their only option was to haul the oil in barrels by wagons over rough dirt roads. The teamsters quickly obtained a monopoly on this overland transport. Teamsters had flocked to the Oil Regions in great numbers following Drake's discovery, recognizing the opportunity for good wages. While the pay was favorable, the work was brutal. Using horse-drawn carts that could carry five or six barrels weighing around 360 pounds each, teamsters loaded the oil and drove it over the rough roads, then unloaded the barrels into oil barges or onto railroad cars. In good conditions, this was slow and arduous work. During rainy seasons, the roads became practically impassable, and wagons often sank up to their axles in mud. Teamsters and their horses also hauled the empty barges back up Oil Creek for the next shipment.

While teamsters provided an essential function for the oil industry, they were widely despised by oil producers and community members. Not only were the rates that teamsters charged widely considered exorbitant, often as much as \$3 or more per barrel, they were also a source of social tension.¹⁴ Teamsters were considered to be a particularly hard-drinking lot who spent most of their spare time boozing and fighting. They drove their horses so hard that it was rare for an animal to survive more than two years of service. Those getting in the way of teamsters faced the prospect of feeling the “black snake” of a whip across their legs.¹⁵ Producers of oil felt unfairly robbed of profits by teamsters, while community members experienced them as a toxic presence. However, with no other way for getting oil to transport points and faced with the ability of the teamsters to keep outsiders from entering the hauling business, there appeared to be no alternative except to tolerate an unwelcome presence. As Ida Tarbell summarized, “[i]ndispensable to the business [teamsters] became the tyrants of the region—working and brawling as suited them.”¹⁶

A standard trope in newspaper articles of the time and early histories of the Oil Regions, the frustrations with the teamsters reflected a pattern that would be repeated time and time again in the oil industry. Control over transport allowed teamsters to hold considerable power within the industry and make handsome profits while withstanding social critique. Though teamsters accomplished this first, their success would later be matched by the railroads and Standard Oil, and then by the parties controlling pipelines.

¹⁴ Ibid., 185.

¹⁵ Tarbell, *The History of the Standard Oil Company*, I, 14.

¹⁶ Ibid.

During the early years of the oil industry, transport was by far the most significant expense. To get a barrel of oil to a seaboard market in 1860 cost an estimated \$11.00 per barrel.¹⁷ By 1862, *Scientific American* estimated the cost of shipments at \$8.00 per barrel.¹⁸ In 1864, things were not much better. Oil cost \$7.00 at the well, but over \$15.00 in New York, meaning that over 50 percent of the cost was allocated to transport (\$1.50 for hauling to a railroad depot, \$3.60 for railroad charges, and \$3.25 for a barrel).¹⁹ In addition, unreliable transport and storage facilities meant that the production of oil far exceeded the amounts that arrived in markets. Williamson and Daum estimate that only 15-20 percent of oil production in the early 1860s actually reached consumers. For instance, of the more than two million barrels produced in 1861, about 94,000 reached Pittsburgh by pond freshet, 135,000 reached the Sunbury & Erie railroad, and the Atlantic & Great Western railroad shipped 70,000 barrels.²⁰ Paul Giddens notes that “[t]he pond freshet always involved a heavy loss of oil; a third of it was lost by leakage before the boats started, and another third was lost before reaching Pittsburgh.”²¹ The remaining oil was lost to leaky barrels, evaporation, and unreliable transport infrastructure.

This system of transport left much to be desired. Newspaper articles bemoaned the presence of teamsters within the community and oil producers railed against the high prices of transport. Moreover, wagons, barrels, and barges could only move so much oil. As production increased from thousands to hundreds of thousands to millions of barrels,

¹⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 107.

¹⁸ *Scientific American*, LXVI (Feb. 27, 1862), 134. As cited in: Ibid.

¹⁹ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906".

²⁰ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 109.

²¹ Paul Henry Giddens, *Early Days of Oil, a Pictorial History of the Beginnings of the Industry in Pennsylvania* (Princeton: Princeton University Press, 1948).

there simply were not enough teamsters, wagons, horses, roads, barges, and pond freshets to get the oil to market. This state of affairs created a powerful incentive for entrepreneurs to develop new ways of transporting oil.

In 1865, Samuel van Syckel introduced the first revolution in the transport of oil by building a gathering pipeline that connected a series of oil wells to a centralized collection point at a railroad depot.²² His efforts were inspired in large part by the prolific wells discovered along Pithole Creek. Despite an estimated three thousand teamsters flooding to the area, transport was slow and expensive. Van Syckel decided that a pipeline crossing the foothills and arriving at the Oil Creek Railroad depot on Miller Farm could be a profitable investment. He took out a loan for \$30,000—approximately \$370,000 in 2005 currency—from the First National Bank of Titusville.²³ He attached three pumps to a five mile pipeline with a two-inch diameter, and was able to force the oil through its length in a continuous flow. The capacity of the pipeline, eighty one barrels per hour, was estimated to do the work of three hundred teams working ten hours a day.²⁴ Van Syckel charged one dollar per barrel and made a small fortune.

To build his pipeline, van Syckel drew on technology that had already been developed, particularly in urban water and gas lighting systems. In addition, others had already attempted to apply pipelines to the transport of oil. Samuel Karns and Heman

²² In this study, I will be distinguishing between gathering pipelines and long-distance pipelines. Gathering pipelines were typically short in length with a small diameter, and their function was to take oil from the well to a connection point where another transport system—either a railroad, canal/river barge, or long-distance pipeline—would ship the oil to its next destination. Long-distance pipelines were much longer in length, had greater diameters, and transported oil gathered at a central location long distances to sites where it would be refined. Van Syckel's pipeline was a gathering pipeline. The Tide-Water pipeline was a long-distance pipeline.

²³ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 7.

²⁴ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 52.

Janes made proposals in 1860 and 1861, respectively, to construct pipelines, but nothing came of their efforts. In 1862, James Hutchings built a thousand foot pipeline from a well-head to a refinery that operated on the siphon principle. When he tried to attach a rotary motor and force the oil uphill, his pump and pipes proved inadequate for the task. Another effort by Hutchings in 1863-64 faced similar problems with leaking pipes and was abandoned when teamsters tore up the pipes.²⁵

Most oil producers greeted van Syckel's breakthrough enthusiastically. It offered a cheaper way to transport oil and alleviated some of the bottleneck. The teamsters, on the other hand, recognized the pipeline as a profound threat to their livelihood. On multiple occasions they sabotaged van Syckel's pipeline, forcing him to post armed guards along the line day and night. An early employee later wrote that "[a]ll of the officials of the company, including the writer, were threatened by the teamsters with transportation to a warmer climate."²⁶ However, the protests of the teamsters did not succeed. As short-distance gathering pipelines spread throughout the Oil Regions, the numbers and social power of teamsters faded rapidly.

At the same, railroads were also rapidly overtaking rivers as the main method for transporting petroleum long distances. Numerous factors encouraged this development. The first was the increase in number of railroads serving the region. By 1866, several railroads were operating in the region, each with a connection to one of the big three railroads—the Pennsylvania headed by Tom Scott, the Erie led by Jay Gould, and the New York Central directed by Cornelius Vanderbilt. Second, iron tanks capable of

²⁵ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 5-6.

²⁶ Alfred Wilson Smiley, *A Few Scraps, Oily and Otherwise* (Oil City, Pa.: Derrick Publishing Company, 1907), 121.

storing thousands of barrels of crude oil came into common use after 1865, when the end of the Civil War made iron more widely available. The introduction of iron tanks aided railroads by gathering large amounts of oil at centralized stations. A third boon was the development of tank cars, reducing the need to transport oil in barrels. Amos Desmore is credited with developing the first innovation by creating 40-50 barrel cylindrical wooden tanks that could be attached to flat cars.²⁷ The more familiar horizontal boiler-type railroad cars were developed in 1868 and soon became the industry standard. With adequate connections in the region, gathering pipelines that could collect large quantities of oil in centralized depots, adequate storage facilities, and tank cars, the railroads became the predominant transporters of oil over long distances.

Interestingly, the lack of iron for storage tanks appears to be one of the few effects the Civil War had on the early oil industry. Despite the large amounts of resources and manpower directed towards the war effort by both North and South, the oil industry never lacked for capital or laborers. The disruptions of the war did have a couple of other effects on the trade. First, it interrupted shipments of turpentine from the South. Turpentine was an essential ingredient in camphene, a widely used artificial illuminant that competed in markets with kerosene. By cutting off the supply of camphene, the war helped create markets for kerosene. Second, when the war ended in 1865, many of the single men in the armies headed to the Oil Regions, thereby expanding the booming production of oil.

Once loaded onto railroads, most of the oil was shipped to refining centers including Cleveland, New York, Pittsburgh, Philadelphia, and Baltimore. At these

²⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 181.

locations the oil was refined into several products including kerosene, naphtha, paraffin wax, and lubricating oils. Just as most oil today is turned into gasoline, in the nineteenth century kerosene was the most valued product. Kerosene was used for indoor lighting and was widely considered to be superior to candle light. Demand for improved illumination was particularly strong in Europe where the majority of American kerosene production was shipped. By 1866, more kerosene was being sold abroad than domestically, a pattern that held throughout the nineteenth century.²⁸

Between 1865 and 1872, there was a relative balance of power within the industry between producing, refining, and transport interests. At least ten different companies operated gathering pipelines, ensuring competitive rates. For the long-distance transport of crude by railroad, producers and refiners considered rates generally favorable because the major trunk lines were in competition with each other for obtaining the agricultural trade from the Midwest, and therefore generally kept rates on oil low. During these several years, both gathering pipelines and railroads entrenched their positions as the dominant methods of transporting oil short and long distances.

This period of balance did not last. The rise of the Standard Oil Company dramatically changed the competitive dynamics of the industry. Volumes have been written on Standard Oil, and it is beyond the scope of this chapter to discuss the history of the “octopus” beyond its broadest outlines.²⁹ However, it is important to note that control over transport—both gathering pipelines and long-distance transport by railroad—was

²⁸ Ibid., 311, 488.

²⁹ The history of Standard Oil is covered by numerous volumes. Among the better are: Ibid; Tarbell, *The History of the Standard Oil Company*; Ralph Willard Hidy and Muriel Hidy, *History of Standard Oil Company (New Jersey): Pioneering in Big Business, 1882-1911* (New York: Harper, 1955); Nevins, *Study in Power*.

central to the ability of John D. Rockefeller's company to form one of the most remarkable monopolies in business history during the 1870s. From its roots as a small Cleveland refiner in 1865, Rockefeller's company managed to acquire control over practically all of the refiners of his city by 1872 and 90 percent of the nation's refining capacity by 1879.

The key factor behind Standard Oil's success was its ability to gain consistently lower rates on the transport of oil. As Ida Tarbell summarized: "It was the rebate which had made the Standard Oil Trust, the rebate, amplified, systematised, glorified into a power never equaled before or since by any business of the country."³⁰ How did Rockefeller use transport to his advantage? First, he benefited immensely from Cleveland's advantageous geography. At first glance, this is a surprising statement. Most of the oil refined during the first two decades of the industry was exported overseas. Therefore, it would seem that shipping the oil 150 miles west of the Oil Regions would add at least 300 miles to the total distance it would need to travel before it could be loaded on ocean-going vessels. Pittsburgh, the Oil Regions, New York, and Philadelphia all seemed to have a more favorable location for oil refining based on shipment distances. Cleveland's only geographic advantage seemed to be for the small trade in western oil shipments.

However, absolute distance between points was only one factor in determining transport costs, and in the context of nineteenth century railroad practice, it was rarely the most important. Competition mattered far more. In this context, Cleveland was uniquely situated. Two railroad systems served Cleveland—the Lake Shore Railroad and the

³⁰ Tarbell, *The History of the Standard Oil Company*, II, 67.

Atlantic & Great Western Railroad—thereby ensuring competitive rates. More importantly, for shipments of refined oil to the eastern seaboard, Cleveland refiners had several options. Both the Lake Shore and Atlantic and Great Western Railroads had connections with the three major trunk lines (the Pennsylvania, Erie, and Central Railroads) for shipments to Philadelphia or New York. In addition, Cleveland benefited from the availability of water transport. Oil could be shipped over the Great Lakes to the Erie Canal or directly to Europe through the St. Lawrence River (see Map 3.1).

The presence of multiple shippers in Cleveland provided Rockefeller with the opportunity to obtain rebates and discounts on his oil shipments by playing competing transport system against one another. He took advantage of this situation masterfully. First, he negotiated with all the shippers to obtain the lowest rates possible. These initial lower rates helped him to build up his business. By 1870, Rockefeller was doing large amounts of business and he could negotiate further discounts by offering railroads bulk shipments. These bulk shipments lowered the railroad's costs by utilizing their investments in tank cars more effectively, allowing them to give Standard Oil lower rates.³¹ This soon turned into a synergistic cycle whereby lower transport costs allowed Standard Oil to increase its business, which resulted in even larger oil shipments. The company could then achieve further rate cuts, which put it in an even stronger competitive position.

³¹ James Deveraux, Vice-President of the Atlantic & Great Western Railroad later testified in court that if bulk shipments of oil could be guaranteed and run regularly, it would lower the capital costs of the railroad by several hundred thousand dollars, because fewer tank cars had to be purchased if they were used more efficiently. Therefore, it was logical for them to give special rates to any supplier that could provide these shipments. Part of his testimony is reprinted in: Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 306.

While Rockefeller's excellent business skills and negotiating acumen played a critical role in obtaining these discounts, it is important to note that he had a geographical advantage as well. Refiners in Pittsburgh and Philadelphia, by contrast, had far less opportunity to negotiate because there was little competition on oil shipments to these destinations. The Pennsylvania Railroad had a near-monopoly on shipments, particularly to the eastern seaboard. Without strong competition, the railroad chose to keep its prices relatively high, thereby disadvantaging refiners in Pittsburgh and Philadelphia.³²

Using his financial advantages from lower transport costs, Rockefeller eliminated his competitors in one of two ways. His preferred method was collaboration, particularly if a rival firm had promising executive talent. Many prominent oilmen ended up joining Standard Oil and profiting handsomely, especially when they brought management skills. If a competitor was unwilling to collaborate, or did not feel Rockefeller was offering a fair price, then Standard Oil would unleash its second tactic: a rate war. They would offer oil in the competitor's region at prices far below market levels and absorb the losses, knowing that their greater capital would allow them to outlast the competition. The strategy of rate wars was particularly effective because Standard Oil did not actually lose nearly as much money as its competitors due to cheaper oil shipments.

In addition to profiting from the long-distance transport of crude oil, Standard Oil also began acquiring control of the gathering pipeline network. There were close to a dozen independent pipeline and storage companies in the beginning of the 1870s, but by the end of 1877 Standard owned a controlling stake in practically all of them. Domination of oil's transport infrastructure—through owning controlling stakes in the

³² Nevins, *Study in Power*, I, 79.

gathering pipelines and storage tank companies and obtaining the lowest rates from railroads—enabled Standard to reap massive profits and eliminate competitors. The fact that Standard was paying \$.85 per barrel or less for shipments to the seaboard while it cost independents \$1.25 to \$1.40 per barrel explains some of this disparity.³³ Eventually, Rockefeller was even dictating to the railroads the percentages of oil they would carry and the rates they would receive.³⁴ By 1878, a typical barrel of oil would be pumped by an independent producer and sent into a Standard-controlled gathering pipeline to be stored in a Standard-controlled iron tank then shipped to a Standard-controlled refinery via a Standard-controlled railroad and sold to consumers through a Standard-controlled marketing group.

This system worked extremely well for Standard as well as the railroad companies, who still considered oil one of their most profitable products despite the high rebates they paid when shipping for Standard. One of the primary reasons the trunk lines agreed to give Standard preferential rates is that Rockefeller eliminated the competition between them for oil. All these railroads were competing for the lucrative Chicago agricultural trade and often engaged in rate wars against each other. The fact that they could hold a steady price for petroleum made it a profitable business. The advantages that accrued to Standard Oil and the railroad companies came at the expense of others, most notably independent oil refiners and oil producers.³⁵ In addition, it has been argued

³³ Tarbell, *The History of the Standard Oil Company*, II, 11.

³⁴ Standard Oil officials defended their lower rates in part as compensation for acting as an “evener” between the major railroad companies, who would otherwise engage in rate wars against each other. The result was that Standard Oil received the lowest rates on transport and even obtained commissions on oil shipped by independent parties. Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 427.

³⁵ In the context of the nineteenth century oil industry, “independent” refers to any oil person not affiliated with Standard Oil.

that consumers of refined oil paid higher prices as a result of Standard Oil's monopoly pricing.³⁶

Independent oil refiners and producers were not blind to the rise of Standard Oil and the role of transport advantages in the growth of the company. Over the 1870s, different actors attempted several responses to confront Standard Oil, including group organization and integrating transport and refining interests. For example, in 1872, independent oilmen formed the Petroleum Producers Union to protest the South Improvement Company scheme, a proposal by Standard Oil and the railroad companies to control oil shipments. By withholding oil shipments from participating railroads, the Petroleum Producers Union helped ensure that the South Improvement Company's plan was abandoned. However, many of the rate structures included in the proposal were soon implemented in other forms.³⁷

Joseph Potts of the Empire Transportation Company led a separate effort in 1877 to challenge Rockefeller's company. Empire owned a series of gather pipelines and railroad tank cars that were shipped on the Pennsylvania Railroad's tracks. With the focus of Standard Oil on refineries in the New York area, both Potts and President Tom Scott of the Pennsylvania Railroad feared they would see a decline in oil shipments. Potts therefore began to purchase refineries in Philadelphia and New York to guarantee that Empire would have an outlet for its oil.³⁸ Standard Oil responded quickly to the challenge by removing its oil shipments from the Pennsylvania Railroad and a general

³⁶ Tarbell estimated that after Standard Oil had eliminated its competitors, prices to consumers increased by a quarter to a third: Tarbell, *The History of the Standard Oil Company*, II, 59-60.

³⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 346-352.

³⁸ For a history of the Empire Transportation Company's conflict with Standard Oil, see: Ibid., chapter 16; Nevins, *Study in Power*, chapter 13; Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", chapter 3.

rate war soon broke out. The Erie dropped its rate from over a dollar to thirty-five cents for shipments east and the Pennsylvania Railroad reportedly carried oil for eight cents a barrel.³⁹ By the end of the summer, Standard Oil had emerged victorious. The Pennsylvania Railroad withdrew its support of Potts and the properties and assets of Empire were sold to Standard Oil, thereby increasing Rockefeller's grip on oil transport.

Transport was not the only problem facing independent producers. Chronic overproduction contributed greatly to the low profits of oil producers. In 1878, drillers flooded to the newly discovered Bradford field (near the New York border) and production skyrocketed. Prices plummeted correspondingly. However, producers noted that Standard Oil was still able to profit during hard times for the rest of the industry. Many of them gathered together under the auspices of the Petroleum Producers Union to seek to control production and fight Standard Oil through political and legal means. For example, the Union introduced bills to the Pennsylvania legislature that would give eminent domain privileges to pipelines, appealed to Governor Harncraft of Pennsylvania to force the Pennsylvania Railroad to establish fair rates on oil transport, and protested the competitive practices of Standard Oil.⁴⁰ These efforts led to a series of investigations that drew public attention to Standard Oil, but did not fundamentally alter the dynamics of the industry.⁴¹

³⁹ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 62.

⁴⁰ Ibid., chapter 4.

⁴¹ See, for instance: Pennsylvania Department of Internal Affairs, *In the Matter of the Investigation Ordered by the Secretary of Internal Affairs of the Commonwealth of Pennsylvania: Upon the Complaint of Citizens, That Certain Corporations Were Transcending Their Corporate Functions and Infringing Upon the Rights of Individual Citizens* (Titusville, PA: 1878); Petroleum Producers Union, *An Appeal to the Executive of Pennsylvania: An Address to Governor John F. Hartranft, Invoking the Aid of the State against the Unlawful Acts of Corporations: Presented August 15, 1878* (Titusville, Pa.: Graham & Lake,

Ultimately, these efforts to fight Standard Oil failed to defeat the octopus.

Instead, the results of these battles usually left Standard Oil in stronger position, as Rockefeller was able to either demoralize his enemies (as in the case of the Petroleum Producers Union) or acquire their assets (as in the case of Empire). By the end of the 1870s, Standard Oil's control over oil transport was nearly complete.

The Tide-Water Pipeline

Astute oilmen knew that oil transport influenced profitability and some of them believed long-distance pipelines could alter the industry's existing balance of power. If they could construct a pipeline to the seaboard that was not controlled by Standard Oil, they might be able to beat "the octopus" at its own game. In 1879, these hopes became physically embodied in the Tide-Water pipeline.

While pipelines had been used since 1865 to move oil from wellheads to railroad depots, the development of a long-distance pipeline was a very different proposition. Gathering pipelines were small-diameter (usually two inches) and short-distance (typically under five miles). Often the oil flowed either by gravity, or was driven by small pumps where there was an elevation gain. Gathering pipeline companies operated as intermediaries between producers and shippers. Long-distance pipelines, by contrast, had large-diameters (five inches and above) and operated over long distances (ranging from a hundred to several hundred miles). Large pumps were needed to force the oil across long stretches of terrain. Long-distance pipeline companies operated as

Printers, 1878); New York Assembly, *Proceedings of the Special Committee on Railroads, Appointed to Investigate Alleged Abuses in the Management of Railroads Chartered in the State of New York*.

intermediaries between gathering pipeline companies and refineries. In other words, the two systems involved different capital requirements, technologies, and customers.

The first effort to create a long-distance pipeline began in 1874. David Hostetter, a former patent medicine salesman, formed the Columbia Conduit Company to build a 32-mile pipeline from the Butler oil field to a point 10-12 miles from Pittsburgh.⁴² His workers laid a 4-inch pipeline with pumping stations every five miles. He immediately ran into trouble, however, as his pipeline had to cross the tracks of the Western branch of the Pennsylvania Railroad. Taking a cue from actions of the teamsters the previous decade, the railroads moved with force against the new competitor. As soon as the pipes were laid under the tracks, railroad employees pulled them out and used their corporate strength in the courtroom to defend their actions. Not content to rely on the law, the railroad men built fortifications out of railroad ties and kept armed guards on site to prevent the completion of the pipeline.⁴³ Frustrated and ready to give up, Hostetter leased the pipeline to Byron Benson, Robert Hopkins, and David McKelvy in April, 1875.

Benson, Hopkins, and McKelvy had been working together for several years. Benson and Hopkins were born on farms in Onondaga County, New York. At the ages of 17 and 16, respectively, they left their homes and traveled west together to seek their fortunes. Failing to strike it rich, they returned to New York in 1854 and began a lumber business. During the Civil War, Benson served as Sheriff of Onondaga County and

⁴² The charter was created in 1872 after a geographically restricted free pipeline bill was passed. See Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 406. Original citation is to *Pittsburgh Commercial* (Aug. 11, 1874) reprinted in *Titusville Morning Herald* (Aug. 13, 1874).

⁴³ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 40.

Hopkins joined the Union Army. After the war, the two moved to Enterprise, Pennsylvania (five miles east of Titusville) and established an oil and lumber company. The men used the lumber mill to obtain regular profits until they found oil in paying quantities. They soon met a young lawyer named David McKelvy and in 1870 the parties created an oil-producing partnership that generated significant income over the next several years.⁴⁴

J. G. Benton, an oil producer and friend of Benson and Hopkins, alerted the men to the pipeline opportunity. Benton had an idea but needed capital to implement his plan. His solution was cost-effective, if not elegant. He realized that if the line was split in the middle at a public crossing of the railroad, the men could make regular oil shipments by carting the oil over the tracks in horse-drawn tank cars. Benson, Hopkins, and McKelvy agreed and leased the pipeline from Hostetter. Benton located a public highway that crossed the railroad near the path of the line and built a storage tank at either side of the line. When the oil arrived at the north side of the tracks, it was pumped from the pipe into a horse-drawn tank car, driven across the railroad tracks, deposited in the pipes on the south side, and sent to Pittsburgh. The railroad company tried to thwart this plan by leaving railroad cars parked on the tracks, but because it was a public highway, a court forced them to stop this practice. With this work-around, the pipeline was able to ship 5,000 barrels a day and earn a good rate of return.⁴⁵

⁴⁴ R. D. Benson, ed., *A Brief History of the Tide Water Companies* (N.p., [1913]), 5-7. Note: this source is a bound and printed transcript of addresses given at a 1913 dinner dedicated to the history of the Tide-Water Company. There is no indicator of the printer and the date is listed as the date of the dinner party. I accessed this document at the Drake Well Museum in Tittusville, PA.

⁴⁵ *Ibid.*, 8.

The success of the Columbia Conduit drew the attention of Standard Oil.

After Rockefeller defeated the Empire Transportation Company, Standard Oil purchased the Columbia Conduit in 1877 as part of their effort to control oil transport. Hostetter reportedly received a million dollars, and paid a quarter of that sum to Benson, Hopkins, and McKelvy to terminate the lease.⁴⁶

A more aggressive pipeline effort came in 1876 from Henry Harley of the Pennsylvania Transportation Company, who proposed a 230-mile pipeline to Baltimore. He employed the noted Civil War general and civil engineer Herman Haupt, who had led early efforts to construct the Hoosac Tunnel, a railroad tunnel in Massachusetts. Despite having completed the survey, drawn up the technical plans, and raised some capital, this effort was abandoned when Harley was arrested for fraudulent dealings in oil. His company had oversold its oil holdings and went into bankruptcy. Standard Oil purchased the gathering pipelines of Harley's company the next year.⁴⁷

In 1878, Benson, Hopkins, and McKelvy purchased the rights to Harley's proposed pipeline to Baltimore using half of the money they were given when Standard Oil bought the Columbia Conduit. They formed the Seaboard Pipe Company and obtained subscriptions for many of the shares, drawing particular support from independent oilmen aligned with the Petroleum Producers Union.⁴⁸ However, questions over the feasibility of the project led to its collapse. The biggest issues were the lack of independent refiners in Baltimore, declining production in the Butler oil fields where the

⁴⁶ Ibid., 9.

⁴⁷ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 270, 273.

⁴⁸ Benson, ed., *A Brief History of the Tide Water Companies*, 10.

line was to originate, and questions over whether the entire 230-mile right-of-way was secure.⁴⁹

Turning their attention to an alternate route, Benson, Hopkins, and McKelvy created the Tide-Water Pipe Company in November of 1878. They would find that the third time was the charm, at least as far as their pipeline efforts were concerned. They came to an agreement with Franklin Gowen, the flamboyant President of the Reading Railroad, to construct a 110-mile pipeline from the newly discovered Bradford oil field east to Williamsport, where the Reading would take the oil to independent refiners in Philadelphia and New York. The Reading agreed to provide half the needed capital—\$250,000, equivalent to about \$3.5 million in 2005—in return for the opportunity to enter the oil trade. Because the Reading's tracks did not extend west of Williamsport, it had previously been reliant on transfers from other railroads in order to obtain any oil business.

The exact lineage of this proposal is unclear. Newspapers reported that Benson was in Philadelphia over the summer of 1878 raising capital for a pipeline project with the Reading Railroad.⁵⁰ However, the official contracts indicate that the agreement was originally reached with H.L. Dilks of the Equitable Petroleum Company, practically the last gathering pipeline company independent of Standard Oil. The original agreements are signed September 26, 1878 between the Reading Railroad and the Equitable Petroleum Company, with an amendment on November 18, 1878 transferring the rights

⁴⁹ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 301; Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 74; Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 438.

⁵⁰ "New Pipeline to the East," *Titusville Morning Herald*, June 13, 1878.

to the Tide-Water Pipe Company.⁵¹ It is uncertain whether Dilks intended to build the pipeline with Equitable or was acting in the interests of the Tide-Water parties before they could arrange a corporate charter. By April of the following year, Equitable, along with its gathering pipelines and storage tanks, had been absorbed by Tide-Water.⁵²

Workers began constructing the pipeline in February of 1879. The company's directors, engineers, and workers had to face a number of technical and competitive challenges. Pipelines had been proven to work with small diameters and over short distances, but no one had yet attempted anything on this scale. Could a pipe sustain the pressure required to pump the oil over the Allegheny Mountains? Would oil be tarnished by extended contact with iron? Would oil spills ruin the farmlands through which the pipe ran? What interference would Standard Oil present? The combination of these challenges led many in the region to dub the effort "Benson's folly."⁵³

Some of the challenges were technical. First, the company had to design its supplies before it could even place orders. The company purchased sixteen to twenty foot wrought-iron pipes with a six-inch diameter from the National Tube Company and the Reading Iron Works, which were larger than any pipes previously used for oil. Each pipe length weighed 340 pounds, and collectively the pipes were estimated to weigh over five million pounds.⁵⁴ Because these pipes were larger and heavier than anything used before, the company had to design new tools—large pipe tongs—that would allow

⁵¹ Contract between Reading Railroad and Equitable Petroleum Company, September 26, 1878. Records of the Reading Railroad, Box 1182, Folder 952. Hagley Museum and Library, Wilmington, DE.

⁵² "Pipe Line Arrangements," *Titusville Morning Herald*, March 31, 1879.

⁵³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 444.

⁵⁴ "The New Pipe Line," *Oil City Derrick*, January 7, 1879.

workers to connect them.⁵⁵ However, simply designing and ordering the parts was not enough. The company had to identify manufacturing companies that were not dependent on the business of Standard Oil in order to be assured that their products would not be manufactured poorly or delivered late.⁵⁶

Second, the company needed to design pumping stations that could force the oil over large elevation gains without exceeding the pressure capacity of the wrought-iron pipes. Most pumps at the time were direct-acting, which created high levels of pressure. Working with the Holly Manufacturing Company, the Tide-Water's engineers developed a tri-plex pump that could deliver seventy horsepower at a steady level of pressure.⁵⁷ This meant that much more force could be delivered to the oil without tearing the pipes apart at the joints. In reviewing the new design, Mr. Holly, president of the pump company, reportedly announced that he fully understood pressure for the first time.⁵⁸

The labor of constructing the pipeline was a grueling process. The path of the pipeline cut through the forests of the Allegheny Mountains where there were few roads. Therefore, large numbers of teamsters were needed just to deliver the pipe lengths fifteen to twenty miles from the railroad depots to their final destination. Teams of eleven men positioned the heavy pipes in the correct position and used the newly designed pipe tongs to screw the lengths together. The muscle power of men and animals provided the energy

⁵⁵ The tongs were made by the Ames Manufacturing Company and had apparently been designed while the men were planning the Seaboard Pipe Company. "Steam Pumps for the United and Machinery for the Tide-Water Pipe Line," *Titusville Morning Herald*, January 30, 1879.

⁵⁶ The decision to purchase supplies from companies not located in the Oil Regions was unpopular with many people, but the managers believed it was necessary because Standard Oil had a great deal of influence over local manufacturers because of their purchasing power. "Progress of the Tide-Water Pipe Line," *Bradford Daily Era*, December 14, 1878.

⁵⁷ Benson, ed., *A Brief History of the Tide Water Companies*, 26-27.

⁵⁸ *Ibid.*, 27.

needed to construct the line.⁵⁹ Similar to the building of coal canals, while the Tide-Water pipeline would play an important role in creating a mineral economy, the energy that constructed it was drawn from the organic economy.

Finally, the natural landscape provided another set of challenges to the line's construction. It was easier to obtain the rights-of-way for the pipeline if the line went through the Allegheny Mountains, but this made building the line that much harder. In addition to the difficulty of getting the pipes and men to the sites of construction, the pipeline had to ascend over fifteen hundred feet to a maximum elevation of twenty-six hundred feet. A severe winter did not help matters, and crews were forced to work around the clock to complete critical sections while navigating through five-foot snow banks.⁶⁰

The technical challenges proved minor in comparison with the competitive threats the new company faced. Standard Oil understood the value its control over transport technologies held, and quickly mobilized several resources to attack the Tide-Water company. Rights-of-way were one of the company's greatest vulnerabilities. At this time, pipeline companies did not have the right of eminent domain, primarily because Standard Oil and the railroads had gone to great lengths to defeat legislative efforts by independent oilmen to achieve this goal in 1873 and 1878.⁶¹ The company had to purchase rights-of-way from landowners for the entire 110 miles. Standard Oil agents immediately began efforts to buy a north-south blocking line that would prevent

⁵⁹ There were reportedly 80 men involved in constructing the line and 40-60 teamsters at the height of construction. "Tide-Water Pipe Line," *Titusville Morning Herald*, April 9, 1879.

⁶⁰ Benson, ed., *A Brief History of the Tide Water Companies*, 22-29.

⁶¹ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", Chapters 2 and 3.

completion of the east-west line. They challenged the leases obtained by the new company along its proposed path and sought to purchase other lands. Two Standard Oil employees were even arrested when they were found to be impersonating Tide-Water officials.⁶² As late as May of 1879, Standard Oil was willing to spend \$20,000, equivalent to more than a quarter million dollars in 2005, to buy two small farms that would break the path of the pipeline.⁶³

Standard Oil pursued the fight on several other fronts as well. When the pipeline was being built, there were seven independent refineries in New York that had signed agreements to get their oil from the new company. Standard Oil purchased control of six of them before the line was completed.⁶⁴ Through its influence in several newspapers, Standard Oil published negative articles about the pipeline and its founders.⁶⁵ In addition to the pressure from Standard Oil, the railroads were also threatened by the new pipeline and offered any resistance they could. The pipeline crossed under the tracks of both the Northern Central and Buffalo, New York & Philadelphia railroads. As soon as the pipes were laid, the railroads sent teams to rip the pipes out. Court injunctions upheld the Tide-Water company's land claims and the pipes were replaced.⁶⁶ In addition, the railroads delayed and misplaced shipments of pipe and supplies along their lines.⁶⁷

⁶² "Obstructing the Tide-Water," *Titusville Morning Herald*, April 17,, 1879.

⁶³ Letter from W.G. Warden to John D. Rockefeller, Sr., 5 May 1879. Box 71, Folder 526, "Warden, W. G., October 1877-February 1880." Papers of John D. Rockefeller, Sr. Part 1: Business Correspondence. Rockefeller Foundation Archives, Rockefeller Archive Center, Sleepy Hollow, New York.

⁶⁴ Benson, ed., *A Brief History of the Tide Water Companies*, 13-4.

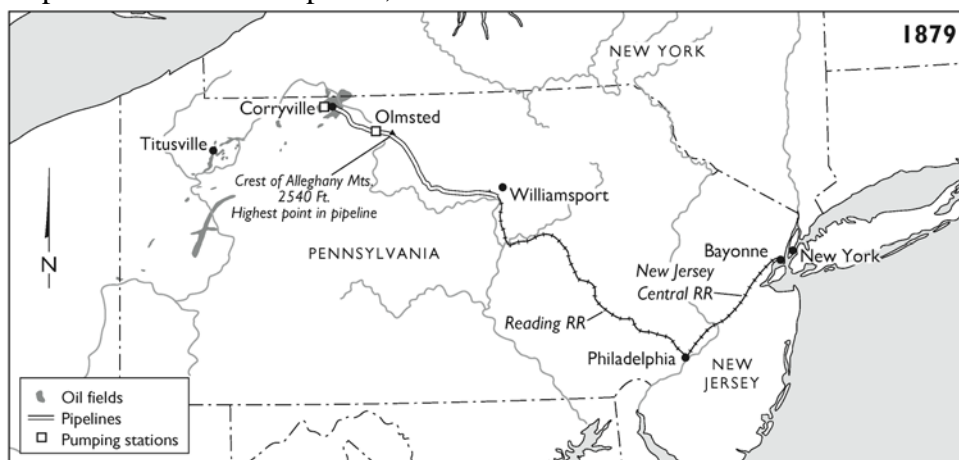
⁶⁵ It is not surprising that many of the most negative articles appeared in the *Oil City Derrick*, which was widely known to be controlled by Standard Oil. For instance, see: "Mr. Zane on the Williamsport Pipe Line," *Oil City Derrick*, December 30, 1878; "'a Citizen' Has His Say About the Tidewater Line," *Oil City Derrick*, May 27, 1879; "Untitled," *Oil City Derrick*, June 11, 1879.

⁶⁶ "An Important Decision," *Titusville Morning Herald*, March 13,, 1879.

⁶⁷ Benson, ed., *A Brief History of the Tide Water Companies*, 24.

Despite the technical challenges and competitive pressures, the Tide-Water pipeline was completed in late May of 1879. Oil entered the pipeline on May 28th moving at about the pace of a man walking. After a short delay to remove pieces of wood left in the line—the result of careless workers or sabotage—the oil arrived in Williamsport in the early evening of June 4th.⁶⁸ For the Tide-water officials, the success of the pipeline was a vindication of their efforts and an impressive technological accomplishment. It would later serve as the model for a 1937 Kern & Hammerstein musical “High, Wide, and Handsome” produced by Paramount Pictures and starring Irene Dunne, Randolph Scott, and Dorothy Lamour.

Map 3.2: Tide-Water Pipeline, 1879



However, simply building a pipeline was not enough for the company to profit from its investments, let alone transform the oil industry. First, the company needed to maintain the pipeline in working order. This required employing at least ten men to patrol the length of the line continually to be sure there were no line breaks.⁶⁹ In addition, the company found that temperature changes could wreak havoc on the pipes.

⁶⁸ Ibid., 26-27.

⁶⁹ "The Tide-Water Pipe Line," *Oil, Paint & Drug Reporter*, June 11, 1879.

The heat of summer caused the pipes to expand and the length of the line buckled. A Tide-Water engineer described it thusly: “The line seemed to be everywhere except in its proper position; telegraph poles and small trees that were fifteen to twenty feet distant when the line was laid were pushed over by it.”⁷⁰ The company therefore buried the pipeline at a depth of eighteen inches at an estimated cost of \$30,000.⁷¹ Third, large deposits of paraffin wax clung to the walls of the pipeline, limiting the flow of oil. In response, the company developed the “Go-Devil”—a wooden ball connected to leather straps and metal scrapers that could be inserted into the pipeline and clear the paraffin wax off the walls.⁷²

Completing the pipeline and maintaining its operations did not end the competitive challenges. In fact, it brought on new issues to deal with. The first salvo came from the railroad companies. The day after the pipeline’s first successful shipment, top executives of the railroads involved in the oil trade gathered in Sarasota, NY and agreed to wage a rate war to put the new competitor out of business. They lowered the prices for shipping crude dramatically: as low as fifteen to twenty cents a barrel to New York. Standard Oil agreed to support the railroads and withheld any shipments from the new line. For the next six months, oil was shipped by all parties at extremely low rates. Tide-Water officials could only find buyers for a quarter of the line’s capacity, about 1,500 barrels per day, and lost an estimated \$100,000 according to the testimony of Gowen before the House Committee of Commerce.⁷³

⁷⁰ Benson, ed., *A Brief History of the Tide Water Companies*, 28.

⁷¹ “Burying Pipe,” *Titusville Morning Herald*, April 14, 1880.

⁷² Benson, ed., *A Brief History of the Tide Water Companies*, 29.

⁷³ As cited in Lloyd, *Wealth against Commonwealth*, 46.

The Tide-Water's losses were nothing compared with the losses of the railroads, however. The railroads were hemorrhaging cash, with their losses estimated as high as ten million dollars.⁷⁴ The pipeline's dramatically lower costs of operation provided a competitive advantage the railroads could not overcome. Defeated, the railroads ended the rate war in early 1880, and came to an agreement allocating a certain percentage of the oil traffic to the Tide-Water pipeline.⁷⁵ Rates were restored to their previous levels, but the business of oil transport would never be the same. As Cornelius Vanderbilt presciently observed: "The oil business is sealed; that is settled; there is no question about that; we [the railroads] won't any of us have the oil business long."⁷⁶ The Tide-Water pipeline had opened a new era in the transport oil.

With the railroads defeated, Standard Oil continued the fight against the Tide-Water on a variety of fronts. Following his preferred strategy, Rockefeller attempted to cooperate with the new competitor and bring them into the Standard Oil conglomerate. Benson's son later reported that Rockefeller offered to purchase the Tide-Water Pipe Company in May of 1879 before the line began operations. This offer was rejected—not necessarily for ideological reasons, but because Benson felt the reported offer of \$300,000 was not compelling.⁷⁷ In 1882, many of the officials at Tide-Water reportedly

⁷⁴ The estimate of \$10,000,000 is probably too high. It came from Franklin Gowen's testimony, and he was prone to exaggerating the truth when it served his interests. However, the losses were significant enough that the railroads were not able to continue the battle. *Ibid.*

⁷⁵ "The New Oil Freights," *Titusville Morning Herald*, February 13, 1880.

⁷⁶ Vanderbilt at Hepburn Committee hearings, as cited in Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 96.

⁷⁷ Ron Chernow, *Titan: The Life of John D. Rockefeller, Sr* (New York: Random House, 1998), 211.

were willing to sell to Rockefeller for a price of \$5,000,000, but it appears Standard Oil was not willing to pay this much.⁷⁸

Standard Oil offered a more formidable attack by purchasing the independent refineries that were expected to be the Tide-Water's customers. This partly explains the low shipments over the line during its first six months. In response, the Tide-Water officials realized that offering low cost transport would not allow them to make money if they had no markets for the oil. They would need to move into the refining and marketing of oil to be assured a stable business. In early 1880 the Tide-Water officials began building their own refineries at locations in Chester, PA and Bayonne, NJ. In the winter of 1881-1882, the pipeline was extended to Tamanend, PA so that oil could be shipped directly to Bayonne on the New Jersey Central Railroad.⁷⁹ Although these projects consumed large amounts of capital and effort, they were necessary for the company to benefit from its ability to transport oil cheaply.

Map 3.3: Tide-Water Pipeline, 1882



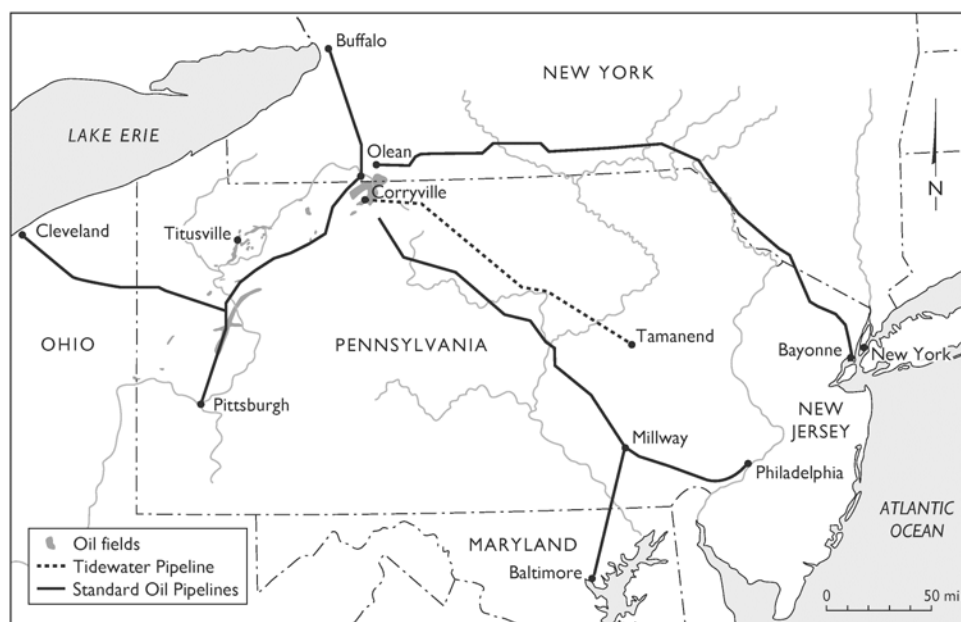
⁷⁸ *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants*, 23 vols. (Washington: Government Printing Office, 1908-1910), Volume I, Petitioners' Testimony, 250.

⁷⁹ Benson, ed., *A Brief History of the Tide Water Companies*, 19.

In addition to attacking the Tide-Water interests, Standard Oil also showed the company the highest form of flattery—imitation. As early as March of 1879, senior Standard Oil officials were urging Rockefeller to begin building his own network of pipelines. They recognized pipelines as both a threat and an opportunity. Pipelines were a threat because they could undermine the existing transport order that Standard Oil controlled. If Standard Oil were to lose its dominance in transport, its ability to monopolize the refining sector of the industry might suffer as well. They were also an opportunity, because if Standard could gain control over pipelines, the organization could retain and even strengthen its control by cutting the railroads out of the loop. Rockefeller was quick to act. By the end of 1879, Standard Oil had already begun construction on a five and a half inch pipeline to Cleveland. In the following years, pipes were laid to New York, Philadelphia, Pittsburgh, and Baltimore. By 1883, Standard Oil had completed four major pipelines to serve its refineries across the country.⁸⁰ The construction of these pipelines was a shrewd move by Standard Oil to ensure its continued dominance of the industry.

⁸⁰ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 100-107.

Map 3.4: Oil Pipeline Network, 1884



Standard Oil's next attacks on the company were more subversive and involved dissension within the ranks of the boards of directors. In September of 1882, a dissatisfied stock-holder—Elisha Patterson—sued the managers of the company for gross fraud and negligence. Patterson had been one of the original stock subscribers when the company was organized in 1878, but had never actually paid for his shares. In 1882, Patterson received a payment of \$20,000 from Standard Oil and used \$5,000 of it to purchase his Tide-Water stock. He immediately filed a lawsuit against the company, citing the fact that the pipeline was operating at levels significantly below capacity. The cause for this low output was soon discovered—a piece of wood had been shoved into the line blocking much of the flow of oil.⁸¹ With this piece of sabotage removed, the line resumed its normal capacity. The court case brought by Patterson was dismissed by the

⁸¹ Tarbell, *The History of the Standard Oil Company*, II, 17-20.

Court of Common Pleas on January 16, 1883.⁸² Several observers argued that the main point of the lawsuit was to discredit the company at a time when it was raising two million dollars in capital to expand its operations. They argued the move was an effort by Standard Oil to prevent its competitor from mounting a more formidable challenge.⁸³ While the company succeeded in raising the money, it had to accept unfavorable terms on the loans.⁸⁴

The next winter an even bolder attempt to overtake the company occurred. The annual board of directors meeting was scheduled for January 17, 1883. Because the necessary financial documents had not been prepared in time, the directors sent notices to stockholders rescheduling the meeting for the following month. With Benson and other directors out of town, a group of minority share-holders with known ties to Standard Oil opened the meeting and elected themselves as directors of the company. With McKelvy as the only director loyal to the original managers present to object, the minority group voted their shares and the shares of other absentees. They installed themselves in leadership positions, and took over the operations of the company. Given the ties of the new directors to Standard Oil, their clear intention was to negotiate some form of agreement.⁸⁵

The original directors immediately filed an injunction arguing the election had been fraudulent. In a case decided on the legal procedures for corporate elections, the presiding judge ruled in favor of the original directors and determined that those present

⁸² Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 109.

⁸³ Tarbell, *The History of the Standard Oil Company*, II, 20.

⁸⁴ Nevins, *Study in Power*, I, 378.

⁸⁵ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 110-112.

had illegally overridden the objections of McKelvy and did not have the authority to vote absentee shares.⁸⁶ The results of the election were dismissed and the original directors were restored to their management positions. Much of the trial centered on the question of Standard Oil's actions against the pipeline, with Tide-Water officials claiming Standard Oil was continually interfering while Standard Oil officials argued that Tide-Water officials had sought them out to collaborate.

By the fall of 1883, the sentiment of the directors had shifted in relationship to their battle with Standard Oil. Several factors, including being exhausted by the continual attacks on their enterprise, difficulties with their refined oil sales, the withdrawal of support by the Reading Railroad when Gowen was ousted as the president, and finally being offered compromise terms that were acceptable, induced the Tide-Water company to enter a pooling agreement with Standard Oil in October of 1883. Under the terms of the agreement, Tide-Water would be allocated 11.5 percent of the traffic of the Oil Regions and Standard Oil would control the remaining 88.5 percent.⁸⁷ For Tide-Water officials, the agreement guaranteed them oil shipments equal to the capacity of their pipeline, adequate markets for their products, and that they would remain an independent corporate entity.⁸⁸

The agreement was a partial victory for the pipeline. The terms were better than most other competitors of Standard Oil had achieved, which indicated that the pipeline had enabled the company to mount a formidable challenge against a monopoly power. In

⁸⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 454.

⁸⁷ The court ruling is reproduced in Tarbell, *The History of the Standard Oil Company*, II, Appendix 39B, 303.

⁸⁸ The pooling arrangement was necessary because it was illegal for Standard Oil to purchase outright control of the Tide-Water Oil Company due to an act of the Pennsylvania Legislature earlier that year that made the merging of competing pipelines illegal. Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 455.

1913, the company president boasted that those who invested in 1882 had received dividends totaling 2000 percent of the initial investment and that the value of the shares had increased fifteen-fold.⁸⁹ In fact, the terms were similar to the arrangements Standard Oil had made with the powerful railroads a few years earlier.

However, the agreement also demonstrated that technological innovation alone could not transform the dynamics of the industry. By agreeing to limit its traffic, the Tide-Water company effectively ended its bid as an independent actor. It would not build a broader network of pipes to compete with the Standard Oil system nor would it offer relief to other independent oil producers. The Tide-Water company would live long and prosper, but never again be a revolutionary force in the transport of oil.⁹⁰

⁸⁹ Benson, ed., *A Brief History of the Tide Water Companies*, 16.

⁹⁰ There is significant debate within the secondary literature as to why the Tide-Water officials agreed to a settlement and the extent to which they betrayed the cause of independents. Some contend that Benson was angling for such a deal from the very early stages. Evidence for this view comes from a letter mailed to John D. Rockefeller from Daniel O'Day in 1880, where O'Day states that Benson took the initiative in reaching out to Standard Oil. As O'Day wrote to Rockefeller: "Yesterday ... I met Benson on the train. We had a long talk about pipe line matters. He told me that he wanted to 'let the bars down,' as he expressed it for any overtures that might be made to his company, with a view of an adjustment of the pipe line questions. He said that he felt that the time had come when the companies should work together with a view of preventing other companies from engaging in the business." On the other hand, Rockefeller's own reflections on the events show a distinct dislike for Benson and Gowen, implying that Benson did not take kindly to attempted negotiations. In contrast to those Tide-Water officials that Rockefeller worked with in 1883, he described Benson and Gowen alternatively as "unreasonable," operating with "a hostile spirit," and "vindictive." Letter from Daniel O'Day to John D. Rockefeller, Sr., 11 March 1880. Box 62, Folder 459, "O'Day, D., 1880-1882." Papers of John D. Rockefeller, Sr. Part 1: Business Correspondence. Rockefeller Foundation Archives, Rockefeller Archive Center, Sleepy Hollow, New York. William O. Inglis, David Freeman Hawke, and Rockefeller Archive Center, *John D. Rockefeller Interview, 1917-1920* (Westport, CT: Meckler Pub. in association with the Rockefeller Archive Center, 1984).

In reviewing the available sources, it seems the truth is somewhere in the middle. Without doubt, Benson and his associates created the Tide-Water Pipe Company to make money, not as a service to independent oil producers. Benson and Hopkins knew that oil production was an unreliable business and from the early days had diversified their investments by operating a lumber mill. Therefore, it is no surprise that Benson reached out to Standard Oil during the rate war on oil transportation in 1880. Finding an agreement that restored rates was the Tide-Water Company's only chance to become a profitable business.

On the other hand, based on the intensity of Rockefeller's dislike for Benson, it seems clear that he had little desire to see his company absorbed by Standard Oil. However, without complete control of his company and a contingent of stockholders seeking a deal with Standard Oil, it seems that Benson lacked the capacity to keep the company growing. It was reported, for instance, that Hopkins and Benson's son

Oil Transport after Tide-Water

After the completion of the Tide-Water pipeline, the industry moved towards the rapid adoption of pipelines as the principal means of oil transport. Standard Oil quickly followed the lead of the Tide-Water Pipe Company and built its own network of pipelines connecting Cleveland, New York, Philadelphia, Pittsburgh, and Baltimore to the Oil Regions by 1883. The railroads continued to carry some oil, but their percentage of crude oil shipments declined dramatically in the following years. According to Allan Nevins, within a few years of the Tide-Water pipeline, the large majority of oil moved through pipes: “It was the beginning of an industrial change which in a few years would turn three-quarters or more of all the crude oil produced away from the rail heads into silent channels underground.”⁹¹

Some Standard Oil officials had been pushing for the development of a pipeline network before the creation of the Tide-Water pipeline, but Rockefeller had opposed this move, largely because his company benefited greatly from its control over railroads. Once the Tide-Water proved the success of long-distance pipelines, however, Standard Oil wasted little time entering the pipeline business. And when they did, they did so with the thoroughness and expertise that characterized their refining operations.⁹²

The first pipeline built by Standard Oil was a five and a half-inch line that spanned a little over a hundred miles from the Oil Regions to Cleveland. Rockefeller contracted with the Chicago and Great Western Railroad to use their rights-of-way in

were in Europe in the summer of 1883 seeking to establish marketing outlets for the company's oil. Developing such a system would have proved very capital-intensive at a time when the company's management was divided. In the end, it makes most sense to see Benson as a pragmatist whose desire to run a profitable business exceeded his opposition to Standard Oil. *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants*, Vol. I, Petitioners' Testimony, 220.

⁹¹ Nevins, *Study in Power*, I, 345.

⁹² Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 446-447.

return for a guarantee that the railroad would receive one-third of the oil shipments to the west and southwest.⁹³ Work began in the fall of 1879 and the laborers completed it in March of 1880. The line had five pumping stations and cost \$500,000.⁹⁴ The pipeline lowered to cost of shipping oil to Cleveland from between thirty-five and fifty cents per barrel by railroad to twelve to twenty cents by pipe. While Standard Oil allowed competitors to purchase oil from the pipeline, they set quotas on the total purchases. Therefore, one refiner was allowed to purchase 85,000 barrels of oil a year for twenty cents a barrel, but Standard Oil cut off shipments when this amount was exceeded.⁹⁵ It did not take long for Standard Oil to use pipelines as a competitive weapon.

Standard Oil also used a pipeline to Buffalo as a strategic weapon. In 1881, a group of independents led by the Kalbfleisch Brothers built a pipeline from the Bradford oil field to Buffalo to serve their refineries. The four-inch Buffalo & Rock City pipeline began operations in August of 1881, charged ten cents per barrel, and had a daily capacity of 5,000 barrels. Having heard of the independents' plan, Standard Oil built its own three-inch pipeline to Buffalo at about the same time. Using its typical tactic of buying up competitors, Standard Oil bought out the independent refiners and by the beginning of 1882, purchased the Buffalo & Rock City pipeline for nearly \$500,000, approximately the cost of construction.⁹⁶ Standard Oil then tore up its own pipeline and

⁹³ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 101.

⁹⁴ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 318.

⁹⁵ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 448-449.

⁹⁶ Hidy and Hidy, *History of Standard Oil Company (New Jersey): Pioneering in Big Business, 1882-1911*, 84.

used the Buffalo & Rock City line. However, rates were immediately increased to twenty-five cents per barrel.⁹⁷

Standard Oil was also interested in building trunk pipelines to its refineries on the eastern seaboard. It first made a deal with the Erie Railroad, paying the railroad \$50,000 to use its rights-of-way and promising to maintain a certain level of oil shipments along the line.⁹⁸ Workers began constructing the six-inch pipeline from Olean, NY to the New York Harbor in July of 1880 and worked from both ends. The line was completed as far as Saddle River, NJ by December of 1881, about sixty miles from Bayonne. Shortly afterwards, Standard Oil began to lay a second six-inch pipeline next to it, doubling the capacity of the line to approximately 24,000 barrels a day.⁹⁹ In 1884, the line was extended to Bayonne with a branch supplying oil to refiners on Long Island.¹⁰⁰ Standard Oil also built a 260-mile six-inch pipeline to Philadelphia in 1882. The line began in Colegrove, PA and traveled to the Atlantic Refining Company's refinery at Gibson's Point in Philadelphia. The following year a 70-mile branch was added to Baltimore.¹⁰¹ Finally, Standard Oil was still operating the Columbia Conduit pipeline to Pittsburgh.

By 1883 Standard Oil had developed a comprehensive network serving its refineries in Bayonne, Philadelphia, Baltimore, Cleveland, Buffalo, and Pittsburgh. There are several things that are notable about this network. First, Standard Oil's close relationships with the railroad companies facilitated the development of its pipeline network. By paying nominal fees for rights-of-way and guaranteeing railroad companies

⁹⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 453.

⁹⁸ *Ibid.*, 449.

⁹⁹ Hidy and Hidy, *History of Standard Oil Company (New Jersey): Pioneering in Big Business, 1882-1911*, 82.

¹⁰⁰ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 126.

¹⁰¹ *Ibid.*, 104.

a percentage of the business, Standard Oil was able to build its pipelines to Cleveland, Buffalo, and New York along the paths of railroads. Second, Standard Oil used its pipelines to regulate competitors, especially in Cleveland and Buffalo. Third, once the network was established in 1883, there were no major competitors for nearly a decade. By investing in pipelines, Standard Oil had not only re-established its control over oil transport; it had strengthened its domination by cutting out the railroads.

Over the next ten years, Standard Oil expanded its system to serve its refineries. It extended its lines into the newly developing oil fields in West Virginia and Ohio during the 1880, including an eight-inch pipeline from the Ohio oil fields to Whiting, Indiana, about 15 miles south of Chicago. Standard Oil established a refinery at this location that eventually led to the decline of Cleveland as a refining center, as Whiting was more geographically convenient for the western trade. In addition, the Tide-Water company extended their pipeline in 1887 from Tamanend to its main refinery at Bayonne, NJ.¹⁰² With its oil flowing exclusively to the New York harbor, Tide-Water sold its refinery in Chester, PA, and concentrated its refining at Bayonne.

¹⁰² The original contract between the Tide-Water Pipe Company and Reading Railroad required that the pipeline not be extended without the Reading Railroad's permission for eight years from the signing of the contract.

Map 3.5: Tide-Water Pipeline, 1887



In the early 1890s, independent oilmen pioneered two major pipeline projects. First, William Mellon of Pittsburgh spearheaded the Crescent Pipeline. Mellon had entered the oil business in 1889 and was in the process of expanding his business when the Pennsylvania Railroad raised the cost of his shipments to the seaboard in 1892. In a deal similar to the proposal of the Tide-Water pipeline, Mellon decided to build a five-inch pipeline from the Oil Regions to Carlyle, PA, where the Reading Railroad would take the oil to the coast. When the Reading switched presidents and refused to honor the deal, Mellon extended the line to Marcus Hook, PA, just south of Philadelphia. The line was 270 miles, could ship 8,000 barrels of oil a day, and was completed in November of 1892.¹⁰³ In his construction efforts, Mellon benefited greatly from the passage of a Pennsylvania law granting pipeline companies eminent domain privileges in 1883.

With his line complete, Mellon began to develop foreign marketing channels in Europe for his oil. In particular, he had connections with several French refiners who were looking for new sources of oil. However, the Panic of 1893 caused Mellon to

¹⁰³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 584.

abandon the oil trade and focus on his other businesses. He agreed to sell the pipeline to Standard Oil in 1893 for a reported \$2,500,000.¹⁰⁴ Like the Columbia Conduit, Pennsylvania Transportation Company, and Empire Transportation Company, a would-be competitor's efforts ended up improving Standard Oil's position.

The second independent effort was longer-lived and offered the most sustained challenge to Standard Oil's dominance in the Pennsylvania Oil Fields. Led by Lewis Emery, an oil producer, representative in the Pennsylvania Legislature, and Standard Oil foe, a group of oilmen came together and formed what eventually became the Pure Oil Company.¹⁰⁵ In the fall of 1892, this group began construction on two four-inch pipelines from the Oil Regions to the eastern seaboard. The first pipeline was designed to ship crude oil to independent refiners while the second pipeline shipped refined oil from the Oil Regions to the eastern seaboard where it would be exported. The notion of a refined product pipeline was radical at the time because conventional wisdom held that exposure to the wrought-iron pipes would tarnish the oil.¹⁰⁶

Emery and his men ran into several of the challenges faced by earlier companies while building their line. At first, the workers hoped to reach the tracks of the New York, Ontario, and Western Railroad at Hancock, NY, so that the railroad could take the oil to the Hudson River to be shipped to the New York harbor on barges. The Erie Railroad, however, refused to let the company lay its pipe under its tracks. Reportedly, the Erie sent several locomotives, armed men, and a brass cannon to the site to be sure that the

¹⁰⁴ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 604.

¹⁰⁵ Along the way, the various affiliated companies were the United States Pipe Line Company, the Producers' Oil Company, and the Pure Oil Company.

¹⁰⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 572.

pipes would not be laid.¹⁰⁷ Emery decided to abandon this route and build the pipeline to Wilkes-Barre, PA, where the New Jersey Central Railroad would take it to New York.

In 1895, the Pure Oil Company continued its efforts to reach the seaboard via pipe. It hoped to secure a line from Easton, PA through New Jersey, but ran into opposition from the Belvidere Railroad (part of the Pennsylvania Railroad system) and later from the Delaware, Lackawanna, and Western Railroad. After four years of litigation in the courts, the railroad won the case and the pipeline route was abandoned.¹⁰⁸ Ultimately, the line was extended to Marcus Hook, PA in 1900 and the Pure Oil Company gave up its attempt to build a line crossing New Jersey. The inability of Emery to obtain rights-of-way through New Jersey demonstrates the influence of state policy on pipeline developments. The eminent domain privileges in Pennsylvania made it easier for independent companies to build pipelines while the lack of such rights in New Jersey supported the position of established powers.

By successfully building two pipelines to the seaboard, the Pure Oil Company became Standard Oil's biggest domestic competitor. The Pure Oil Company produced, transported, refined, and marketed oil. Moreover, by innovating with the first refined product pipeline, the company reversed the geographic disadvantage that had previously hampered refiners in the Oil Regions. By making it possible to ship refined oil at rates similar to the shipments of crude oil, it erased one of the major barriers to refineries in the Oil Regions.

¹⁰⁷ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 175.

¹⁰⁸ Ibid., 181.

By 1900, pipelines were the dominant technology for the transport of oil. The location of these lines influenced the regional distribution of oil. In addition, there were important technological differences between pipelines and the transport infrastructure networks that preceded them.

For example, pipelines carried a single product in a single direction to a single point. While there were no technical obstacles to drawing off oil at points in-between the ends of the lines, this rarely happened in practice. In addition, oil only flowed in one direction—it was not a reciprocal trade.¹⁰⁹ By contrast, railroads, like canals, could move a variety of goods to many places along the paths of their tracks. Railroads, therefore, offered the possibility of reciprocal benefits in regional development, similar to the way anthracite canals helped create a thriving iron industry along their routes. The only possible reverse flow along pipelines was capital, although almost all of the money was funneled to capitalists in eastern seaboard cities. Even though the profits of railroads usually remained in eastern seaboard cities, trains could bring people, supplies, and goods to the Oil Regions that could bolster regional development. Pipelines funneled a valuable resource away from the Oil Regions while returning very little.

A second feature of pipelines was that they operated continuously, invisibly, and with little human interaction. Unlike railroads where tank cars needed to be coordinated, trains scheduled, and pick-ups and drop-offs implemented, pipelines operated around the clock with steady flows of oil.¹¹⁰ Trains with their loads could be seen crossing the

¹⁰⁹ In theory it was possible to reverse the flow of oil through pipelines but only by redesigning and relocating the pumping stations, an expensive and time-consuming process. I have found almost no references to this having been done in practice.

¹¹⁰ There were small variations in the amount of oil shipped from day to day, week to week, or month to month depending on available supply and market demand, but these fluctuations were minor.

landscape while most pipes were buried one to two feet under the ground. While pipelines did require several humans to keep them operating—usually a foreman, two engineers, two assistant engineers, four firemen, a telegrapher, and line walkers for every pumping station in addition to a management team coordinating the buying and selling of oil—this was far less than the elaborate labor system required to keep railroads running.¹¹¹ Moreover, the labor of operating pipelines was focused on keeping the pumping stations in working order, not actually touching the oil. Oil could be drilled at the well-head, shipped in a gathering pipeline to a storage tank, then pumped to the seaboard in a pipeline and delivered to refinery stills without a human hand ever touching it.

The invisibility of pipeline transport helps make oil into an abstract commodity. When we fill our tanks with gas or heat our homes with oil, we do not know where the petroleum comes from, and the only contact we are likely to have is if the gas pump overfills the tank and splashes us. Invisibility and abstraction dissociate consumers from the social effects of oil use. We know that oil production leads to environmental damage, unstable geo-political relationships, and other negative consequences, and yet we continue to exacerbate these problems through consumption. While there are many explanations for this dependence, the abstraction of oil as a commodity makes it easier for consumers to divorce themselves from the consequences of their actions. Ever since the construction of the Tide-Water, pipelines have been part of making oil an invisible and abstract commodity.

¹¹¹ Hidy and Hidy, *History of Standard Oil Company (New Jersey): Pioneering in Big Business, 1882-1911*, 82. As Alfred Chandler demonstrated, the complexity of railroad operations gave a great impetus to the rise of large bureaucratic organizations. Alfred Dupont Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: Belknap Press, 1977).

Third, pipelines significantly lowered the cost of transporting oil. Although actual pipeline operating costs were rarely stated explicitly, most estimates place the cost at less than twenty cents per barrel from the Oil Regions to the seaboard while prevailing railroad rates had been approximately a dollar per barrel.¹¹² To put this into context, after 1878 the price of crude oil rarely exceeded one dollar, meaning that with railroads, transport comprised half the cost at seaboard locations.¹¹³ With pipelines, the cost of transporting oil represented a smaller fraction of the total costs, thereby encouraging its consumption at more distant locations. In addition, pipelines helped give rise to new uses of oil. For example, the use of petroleum for fuel oil was not practical unless it could be shipped very cheaply. It takes about five barrels of oil to get the energy equivalent of one ton of coal.¹¹⁴ If shipments cost five dollars in addition to the price of crude, then fuel oil could not compete with coal (anthracite was being sold at the mines for between \$1.41 and \$2.01 between 1880 and 1900 with transport costs that rarely exceeded \$2.00 per ton).¹¹⁵ On the other hand, if five barrels of crude oil could be shipped for less than a dollar, petroleum could compete with coal as a source of heat and power in many markets. Therefore, pipelines helped lay the groundwork for the intensive consumption of fuel oil and gasoline in the twentieth century by lowering its cost to consumers.

¹¹² As examples, Standard Oil charged twelve to twenty cents per barrel to pipe oil over 100 miles from the Oil Regions to Cleveland, the Tide-Water pipeline estimated its cost as 16.67 cents per barrel to ship oil to the seaboard, and Standard Oil offered to ship oil from the Oil Regions to the seaboard for the Philadelphia Railroad at rates of between six and ten cents per barrel. See respectively: Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 448., Francis Buente, *Autobiography of an Oil Company* (New York: Tide Water Oil Company, 1923), 23., and Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 127.

¹¹³ Price information from *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 713-715.

¹¹⁴ One barrel of Pennsylvania crude has a BTU value of 5,550,000 while a ton of anthracite coal has a BTU value of 25,400,000. Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 499.

¹¹⁵ See Chapters 1 and 2 for details on transportation of anthracite. Price information from: United States Geological Survey, *Mineral Resources of the United States, 1901*, 301.

Conclusion

The story of the building of the Tide-Water pipeline and the company's struggles with Standard Oil is a fascinating tale full of conflict, intrigue, and subterfuge. In addition, it had important short-term and long-term impacts on the development of the oil industry and the energy patterns of the mid-Atlantic region.

First, this case study demonstrates the crucial role played by transport infrastructure in determining power relationships within the early oil industry. The teamsters, the railroads, and later Standard Oil had all used control over transport to dominate the industry at one point in time. The introduction of long-distance pipelines in 1879 provided new organizations with the opportunity to reshape the power relationships of the industry.¹¹⁶ The Tide-Water company used pipelines to carve a space for itself within the industry. Standard Oil recognized the threat pipelines represented to its interests and moved quickly to appropriate the new technology by attacking Tide-Water and developing its own network. The railroads could not adapt to the pipelines and as Vanderbilt predicted, lost their role in the oil trade.

However, although pipelines provided a competitive opening, technology alone was not sufficient to alter the balance of power within the industry. Because Standard Oil was quick to build its own network of pipelines, it used the new technology to entrench its position. Moreover, the Tide-Water company was not able to succeed simply by lowering the cost of oil shipments. The company had to fend off attacks from Standard Oil and develop its own refining and marketing operations to stay in business. In the end,

¹¹⁶ In this manner, it can be understood as an example of a disruptive technology as described by Clayton Christensen. Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business School Press, 1997).

the Tide-Water Company agreed to a compromise settlement with Standard Oil that guaranteed profitability but ended its bid as an independent company. Pipelines created new possibilities: how the various parties reacted to these opportunities determined the outcomes.

The case also reveals the important role played by governments in structuring market conditions along with the influence of corporations on government decisions. Pipelines were at a distinct legal disadvantage vis-à-vis railroads because they lacked eminent domain privileges. As a result, a company wishing to construct a pipeline had to purchase unbroken rights-of-way for many miles, leaving them subject to being blocked by competitors, harassed by railroads, and extorted by local landowners charging high fees for the use of small pieces of land. Legal efforts to achieve such rights were consistently defeated by the combined strength of Standard Oil and the railroads, which saw such legislation as a threat to their interests. Standard Oil and the railroads were able to parlay their financial strength and monopoly positions into legislative influence that would help ensure the status quo. As a result, the actions of the Pennsylvania Legislature structured market conditions in favor of entrenched interests, which in turn, increased the ability of corporations like Standard Oil and the Pennsylvania Railroad to further influence the legislative process.

Finally, the development of pipelines created a new energy landscape for the flow of petroleum. Once constructed, pipelines could ship oil hundreds of miles for a fraction of the cost of other technologies. Crude oil cost as much as \$8.00 per barrel to ship from the Oil Regions to New York in 1863, or more than twice the cost of oil at the well. Typical railroad prices for comparable oil shipments were between eighty cents and a

dollar and a half per barrel, approximately the same cost as the oil itself. Pipelines, on the other hand, could ship oil hundreds of miles at a significantly lower rate—as little as five to ten cents per barrel. By rendering the cost of transport almost irrelevant, pipelines created a landscape in which cheap and abundant oil was available in the mid-Atlantic’s industrial centers. As we will see in the next chapter, this new energy landscape enabled the ever-increasing consumption of petroleum, thereby deepening the mid-Atlantic’s transition into a mineral economy.

Chapter 4: Piping Petroleum, Consuming Crude: Oil Flow and Usage Patterns in the Mid-Atlantic, 1860-1900

The history of the Tide-Water pipeline demonstrates the importance of transport infrastructure within the competitive dynamics of the oil industry. How oil was transported shaped who made money and which parties would gain broader control over production, refining, and marketing. However, the transport of petroleum was not only important from an intra-industry perspective. Waterways, railroads, and then networks of pipelines structured the flows of oil throughout the mid-Atlantic and America during the last four decades of the nineteenth century, thereby influencing where oil went, how it was used, and the development of a mineral economy.

Once crude oil was refined into kerosene, lubricants, and fuel oils, consumers used these products for light, reduced friction, and power. In the process, they deepened the region's transition into a mineral economy. At the same time, the expansion of the petroleum industry was linked to the extension of the region's industrialization, new political responses to corporations and monopoly capital, and the creation of a fossil fuel-dependent society. This chapter explores these developments by analyzing the flow of oil along transport infrastructure networks, the effects of new consumption patterns on the creation of a mineral economy, and the broader significance of these changes.

Oil Flows

The oil boom following Colonel Drake's discovery in 1859 drew thousands of speculators from all over the United States into western Pennsylvania's Oil Regions.

However, the products of their labor and the concentrated energy bounty of millions of years of captured sunlight flowed in the opposite direction. The great majority of the oil drilled and collected by these speculators was funneled away from western Pennsylvania to refineries throughout the United States where it was processed into products including kerosene and lubricating oils. From the refineries, these products were distributed to consumers around the nation and the world.

How and where oil flowed was neither natural nor inevitable. Instead, transport infrastructure played a crucial role in determining where oil went. Waterways, railroads, and pipelines each had their own geographic logic that privileged certain places and regions over others. The impacts of transport infrastructure on the changing geography of American refining clearly demonstrate the interconnections between energy landscapes and regional development.

Waterways (1859-1865)

Titusville had very little transport infrastructure in 1859. There were no railroad stops nearby and the roads were mostly dirt paths. Therefore, the oil industry turned to the transport system that humans had been using for thousands of years to move bulk goods: waterways. By dramatically reducing friction and sometimes providing a current, waterways enabled humans to move heavy items with relatively minimal effort. Rivers, lakes, and seas were the favored transport systems of organic economies for this reason. Waterways had limitations, though. Most obviously, they were sited by nature, not humans. People had to direct their goods to the places rivers flowed, which were not

always the most desired destinations.¹ Second, rivers reflected seasonal variations.

They might freeze in the winter, be dangerously full during the spring thaw, and too shallow during the hot months of summer.

In the first years of the oil industry, there was only one usable waterway to a larger market: Oil Creek. This small stream ran for about 16 miles from Titusville to Oil City, where it connected with the Allegheny River.² At this point, the oil could be loaded onto larger boats and shipped the remaining 130 miles to Pittsburgh.³ However, the shallow depth of Oil Creek frustrated the efforts of oilmen, particularly during the summer. To improve the river for their needs, oilmen used the system of pond freshets developed by the local lumber industry.⁴ For several years, lumbermen had erected temporary dams to capture large pools of water. When the dams were dismantled, they released waves of high water that could float the lumber downstream. By the early 1860s, oilmen were coordinating two to three freshets per week, often involving hundreds of barges carrying tens of thousands of barrels.

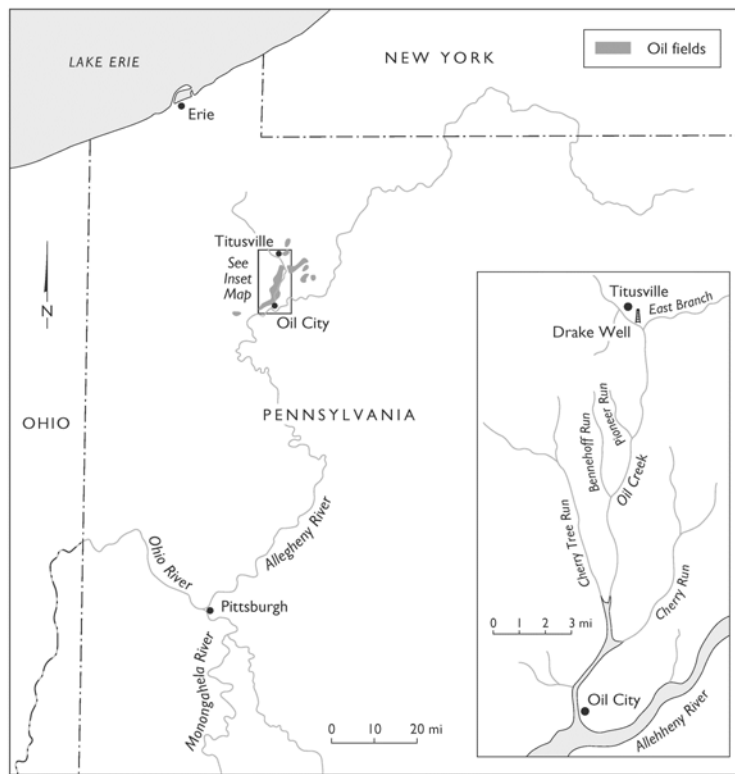
¹ Canal technology could dramatically improve waterways for human transport and in some places open trade routes in new directions. However, for the most part, American canals in the antebellum period largely followed the paths of existing rivers.

² Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 87.

³ Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", 3.

⁴ Pond freshets were also important for the development of the anthracite coal trade. The Lehigh Coal & Navigation Company used hydro-static gates on dams to create artificial waves of high water that could transport coal to market.

Map 4.1: Oil Creek



The energy landscape of water transport privileged Pittsburgh, which was the nearest large manufacturing city that could be reached by boat. Once the oil reached Pittsburgh, it was refined and then shipped west and south along the Ohio River or east on the Pennsylvania Railroad. To a lesser extent, transport along waterways also encouraged refining centers at Buffalo due to its access to the Erie Canal and Great Lakes. From Buffalo, oil could be shipped west to Cleveland and east to New York City. In addition, the general expense and difficulty of shipping crude oil encouraged refining in the Oil Regions themselves. In the early 1860s, only 60 to 65 percent of a barrel of crude oil could be successfully turned into saleable refined oil.⁵ Therefore, oil refined at

⁵ Nevins, *Study in Power*, I, 26.

the site of production lowered the cost of transport because it reduced the absolute amount of oil that needed to be shipped.

Although data on the early oil industry is fragmentary, Table 4.1 indicates that the geography of refining reflected the logic of waterways. Pittsburgh was the clear leader with nearly 40 percent of the nation's refining capacity. Refiners in the New York City area possessed about a quarter of the nation's capacity while the Oil Regions handled an additional fifth of the volume. By contrast, cities without water connections to the Titusville area acquired only small amounts of the trade. For example, Philadelphia, Baltimore, and Boston collectively represented no more than 10 percent of the total industry.

Table 4.1: Geography of Oil Refining, 1864-1865⁶

City	Capacity of refineries (barrels per day)	% of total
Pittsburgh	4,500	39
Philadelphia	600	5
Boston	500	4
New York – New Jersey	3,100	26
Cleveland	800	6
Oil Regions	2,160	19
Erie	...	<1
Baltimore	20	<1
Elsewhere	...	<1
Total	11,680	100

⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 291. The original sources for this data are: *Forty-First Annual Report of the Philadelphia Board of Trade* (Philadelphia, 1873), Thurston, *Pittsburgh and Allegheny in the Centennial Year*; Maybee, *Railroad Competition and the Oil Trade, 1855-1873*; *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*; J. T. Henry, *The Early and Later History of Petroleum, with Authentic Facts in Regard to Its Development in Western Pennsylvania* (Philadelphia: Jas B. Rodgers Co., 1873); William Wright, *The Oil Regions of Pennsylvania: Showing Where Petroleum Is Found; How It Is Obtained, and at What Cost* (New York: Harper & Brothers, 1865).

Railroads (1865-1883)

The energy landscape of railroads restructured the geography of the nation's refining industry. Railways were a revolutionary technology because they broke the links between nature and transport that had long shaped human trade patterns. In contrast to waterways, rails could be built in whatever direction served human needs and operated year-round.⁷ While nature still mattered—features such as mountains and river crossings increased the cost of construction—the iron horse represented an important break from the past.⁸

Railroads began to dominate the transport of crude oil by 1865. Three railroad systems were involved: a local connector, the eastern trunk railroads, and railroads to the west. The first great challenge was simply to create connections between the Oil Regions and existing railroad systems since the nearest depot was twenty miles away from Drake's well. A group of oil producers addressed this problem by building the Oil Creek Railroad in 1862 between Titusville and Corry, PA. From Corry the oil could be sent west along the Atlantic & Great Western to Cleveland or east to Salamanca, NY and transferred to the Erie Railroad for delivery to New York City. As new oil fields were discovered, the Oil Creek Railroad was periodically extended to transport oil from those areas to central depots. In this capacity, the Oil Creek Railroad operated as a local

⁷ The dichotomy between waterways and railroads was significant, but not absolute. The natural world (particularly mountains) still shaped the routes of railroads and canals could (at great expense) be built in places where rivers were not already flowing. In practice, railroads offered people much greater flexibility over transport routes.

⁸ On the impacts of railroads, see: John Stilgoe, *Metropolitan Corridor: Railroads and the American Scene* (New Haven, CT: Yale University Press, 1985); Wolfgang Schivelbusch, *The Railway Journey: The Industrialization of Time and Space in the 19th Century* (Berkeley, Calif.: University of California Press, 1986); Cronon, *Nature's Metropolis: Chicago and the Great West*.

connector, bringing the output of various oil fields to the depots of other railroad systems.⁹

Eastern trunk lines and railroads to the west carried the crude oil from centralized depots like Corry to refineries in large manufacturing cities. The Pennsylvania, Erie, and New York Central railroads were the three great eastern trunk lines connecting the eastern seaboard with the west. By 1865, all of these systems had created connections with the Oil Regions and transported most of the nation's crude oil production to their main hubs: Pittsburgh and Philadelphia for the Pennsylvania and New York City for the Erie and Central railroads. The Baltimore & Ohio extended its tracks near Pittsburgh in the early 1870s, thereby encouraging the growth of refining in Baltimore. In addition, two railroads shipped oil west, primarily towards Cleveland and Chicago: the Atlantic & Great Western and Lake Shore railroads (see Map 3.1).

Connections made railroad transport of crude oil possible; competition structured where it went. Because oil was not a perishable commodity, the cost of its transport was far more important to most parties than the speed at which it was delivered.¹⁰ And nothing structured the cost of railroad transport more than competition. Where a railroad was the only carrier in the region, rates tended to be high. On routes where there were competitors, rates were much lower. For example, William Cronon demonstrated that railroad rates on transporting wheat from Chicago to the eastern seaboard were significantly lower during the summer months when the waterways of the Great Lakes

⁹ On the railroads serving the oil trade, see: Maybee, *Railroad Competition and the Oil Trade, 1855-1873*; Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*.

¹⁰ Even though lots of oil was lost during transit in the early years of the industry, this was due to the poor quality of shipping containers, not instability of the oil itself. By the time tank cars for railroads were in common use in the mid-1860s, losses during shipment were minimal. Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 181.

offered competition. In the winter when water routes were closed, railroad rates increased.¹¹ In other words, rates were determined more by the price that people would pay than the railroad's costs of operation.

The practice of creating railroad rates based on competition led to a plethora of complaints. Newspapers throughout the latter half of the nineteenth century were littered with angry letters denouncing the abuses of railroad companies. These missives usually focused on the seeming arbitrary nature of rates and their pernicious impacts on farmers and small producers. Not only did rates vary dramatically from season to season, it was widely reported that large shippers could obtain substantial rebates on their goods, thereby giving them an unfair advantage.¹² For many people it seemed that railroad rates should be derived from how far goods traveled, not the degree of competition.

The situation was no different in the oil industry. Competition structured rates on oil traffic and therefore the flows of oil.¹³ Moreover, competition was especially fierce for the oil trade because it was part of the broader efforts of the trunk lines to secure dominance in the lucrative trade between the eastern seaboard and Chicago. The most

¹¹ Cronon, *Nature's Metropolis: Chicago and the Great West*, 86-88.

¹² The primary and secondary literature is replete with references to the abuse of railroads. See, for instance, Johnson, "The Development of American Petroleum Pipelines: A Study in Private Enterprise and Public Policy, 1862-1906", chapters 2 and 3; Maybee, *Railroad Competition and the Oil Trade, 1855-1873*; Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, chapters 8 and 16.

¹³ The infamous history of the South Improvement Company, an 1872 arrangement between several of the railroad companies and refiners, shows that competition structured rates more than absolute distances. In an effort to regulate the trade, the parties agreed to a system whereby shipments of crude oil would cost the same whether it went to Cleveland (150 miles) or Pittsburgh (120 miles). Refined oil shipments to the eastern seaboard would cost the same whether they went from Cleveland (630-760 miles depending on whether was shipped on the Erie or Central), or Pittsburgh (350 miles). Refined oil from the Oil Regions (roughly 400 miles) to the seaboard would cost ten cents more per barrel than from Pittsburgh (a shorter distance) or Cleveland (a longer distance). Even though the particular details of the South Improvement Company plan were never implemented, they reflect the considerations that structured rate decisions for the railroads. The contract of the South Improvement Company is reprinted in: Petroleum Producers Union, *An Appeal to the Executive of Pennsylvania: An Address to Governor John F. Hartranft, Invoking the Aid of the State against the Unlawful Acts of Corporations: Presented August 15, 1878*.

competitive points along these lines were between the Oil Regions and New York, where all three trunk lines operated, and the stretch between the Oil Regions and Cleveland. In both these situations, there was additional competition during the summer months from water shipments on the Great Lakes and Erie Canal. By contrast, there was little competition between the Oil Regions and Pittsburgh or Philadelphia, where the Pennsylvania Railroad was the only major shipper. Because the Pennsylvania wanted to ship oil long distances, it discouraged the trade to Pittsburgh. As Allan Nevins noted: “One of the chief reasons for Pittsburgh’s loss of ground lay in the outright unfairness of the Pennsylvania Railroad to the city.”¹⁴

Oil shipments soon showed a shift that reflected the energy landscape of railroads (Table 4.2). Refiners in Cleveland and the New York harbor expanded their capacity significantly while those in Pittsburgh and the Oil Regions experienced the greatest losses. Cities such as Baltimore, Philadelphia, and Boston did not dramatically improve their position (most of the gains represented by Philadelphia in 1881 were a result of the Tide-Water pipeline).¹⁵

Of course, human actors shaped these outcomes as well. The fact that John D. Rockefeller began his business in Cleveland and was a particularly astute negotiator for railroad rebates played an important role in the rise of that city’s refining prominence. However, it is equally important to note that without operating in a city served by two railroads and a major waterway, Rockefeller would have had a much more difficult time

¹⁴ Nevins, *Study in Power*, I, 79.

¹⁵ While Table 4.2 measures refining capacity, not output, records of crude oil shipments from 1880 indicate that these measures give a good indication of actual practice. In that year, New York received 7,622,979 barrels of crude oil, Pittsburgh 1,919,854, and Cleveland 2,638,671. Philadelphia received 1,773,827 barrels, while 742,079 went to Baltimore, 121,280 to Boston, 380,021 to the Oil Regions, and 207,975 to points along the Ohio River. Stephen Farnum Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products* (Washington: Government Printing Office, 1885), 271.

turning the energy landscape of railroads to his advantage. Given the realities of railroad space in the early 1870s, it is difficult to imagine the possibility of an entrepreneur in Pittsburgh or Philadelphia dominating the transport of oil the way John D. Rockefeller did.

Table 4.2: Geography of Oil Refining, 1873, 1881¹⁶

Region	1873 (refining capacity in barrels per day)	1881 (refining capacity in barrels per day)
Cleveland	12,732	21,425
Pittsburgh	8,990	16,765
NY-NJ	9,790	36,871
Philadelphia	2,061	15,457
Baltimore	1,098	
Erie	1,168	
Boston	600	
Buffalo	450	
Oil Regions	9,231	7,260
Others	450	
Total	46,570	97,760

Pipelines (1883-1900)

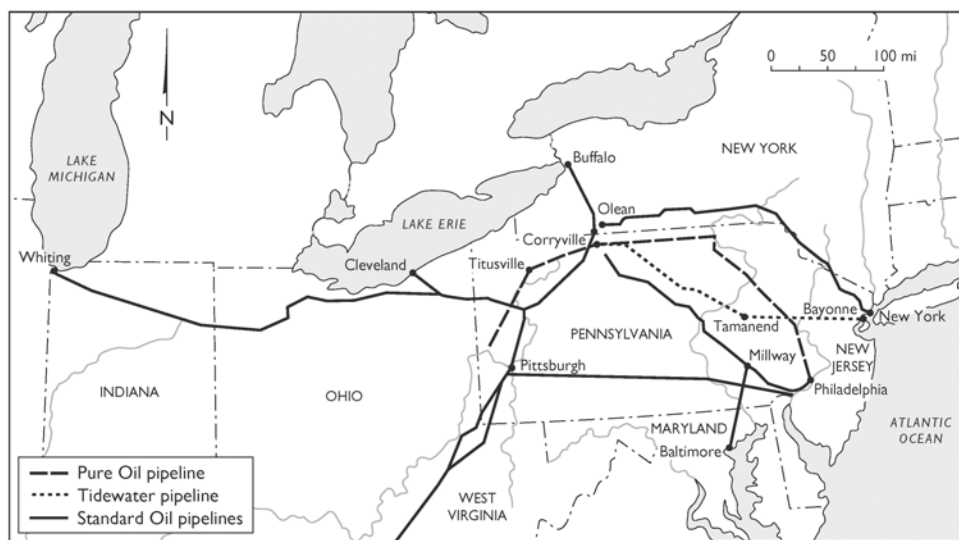
After the construction of the Tide-Water pipeline, the movement of crude oil from well-head to refinery quickly switched from railroads to pipe lines. The energy landscape of pipelines was similar to railroad space, but it was not identical. It was similar because Standard Oil built most of the region's pipelines. Although the Tide-Water pipeline pioneered the shift, Standard Oil's system handled over 85 percent of the traffic by 1883. Since Standard Oil had already established its main refineries in Cleveland and New York, it chose to build pipelines to serve these existing locations rather than to create new ones. In addition, Standard Oil used its close relationships with railroads to build its

¹⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 473. Source for 1873 data: Henry, *The Early and Later History of Petroleum, with Authentic Facts in Regard to Its Development in Western Pennsylvania*, 315-24. Source for 1881 data: House of Representatives, "Report on Investigation of Trusts," 232-35.

pipelines along the rights-of-way of the railroad companies. In this sense, the energy landscape of pipelines reflected and reinforced the patterns of railroads.

However, pipelines could and did introduce shifts into the geography of refining. For example, a pipeline could lower the cost of shipping oil along a route where railroad competition did not exist. Building a new railroad simply for the movement of oil would cost far too much, but pipelines (while not cheap) were much less capital-intensive. Therefore, while Philadelphia and Baltimore did not benefit from railroad competition driving down the cost of oil shipments, the construction of pipelines to these cities put their refiners on a more competitive basis. In other words, pipelines reduced the importance of competition between railroads and waterways for the geography of refining.

Map 4.2: Pipeline Network, 1900



The system of pipelines also led to a relative decline in Cleveland's importance as a refining center. During the 1870s, Cleveland benefited from cheap oil shipments, the

presence of John D. Rockefeller's operations, and its site as the westernmost refining center. However, as the geography of the nation's population expanded westward, Standard Oil chose to shift much of its western refining to its Whiting refinery outside Chicago. Thus, while New York, Philadelphia, Baltimore, and Whiting expanded their output considerably, Cleveland saw a relative decline. In fact, the loss was more significant than Table 4.3 indicates. Even though Cleveland's refineries maintained a large capacity, their actual output was much lower. In 1904 Standard Oil only processed 1,039,385 barrels of oil in that city, whereas 9,720,950 barrels were refined at Philadelphia, 10,590,381 barrels at the main refinery in Bayonne, NJ, and 8,192,945 barrels at Whiting.¹⁷

A final shift occurred with the innovation of refined oil pipelines. In 1895, a group of oilmen from the Titusville area decided to construct a refined oil pipeline to lower the transport costs of their kerosene. Despite beliefs that iron pipelines would corrode refined oil and decrease its quality during shipments over long distances, the United States Pipe Line Company—later part of the Pure Oil Company—succeeded in their efforts.¹⁸ As a result, this pipeline made it economically feasible for refiners in the Oil Regions to compete with seaboard refiners since shipping refined oil via railroad was much more expensive than transporting crude oil in pipelines.

The impacts of pipelines on the geography of oil refining can be seen in Table 4.3. New York remained the leader in refining capacity while Philadelphia grew

¹⁷ *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants*, Petitioner's Exhibits, vol. 8, p. 940, Petitioner's Exhibit 393.

¹⁸ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 571-72; Industrial Commission, "Preliminary Report on Trusts and Industrial Combinations," 651. The historical record does not make it clear what techniques the company used to maintain the quality of the oil.

significantly. Whiting grew dramatically at the expense of Cleveland as much of the latter city's large refining capacity went idle. Refiners in the Oil Regions increased their operations while Pittsburgh, Baltimore, and Buffalo retained small amounts of the trade.

Table 4.3: Geography of Oil Refining, 1884, 1888, 1895-1897¹⁹

	1884		1888		1895-1897	
	Standard	Independent	Standard	Independent	Standard	Independent
Cleveland	22,000		22,000	3,310	20,000	3,310
Pittsburgh	.....		.....	4,103	...	5,000
NY – NJ	43,000		49,266	3,500*	55,000	7,000
Philadelphia	13,000		17,200	3,500*	45,000	3,500
Baltimore	.....		2,000	610	3,000	...
Whiting, IN	.....		...	...	36,000	...
Toledo-Lima	.....		...	...	7,000	7,000
Buffalo	1,600		3,000	1,500	4,500	...
Oil Region	.....		12,000	9,000	7,000	12,000
Other	.....		...	4,000	2,500	...
Standard acquisitions (post Jan 1, 1888)	.....		2,000		3,000	...
Total	96,000	28,868	110,771	29,523	183,000	37,810
Total U.S.	124,868		140,294		220,810	
% Standard	78%		79%		82%	

* includes Tide-Water refining capacity

From the Refineries: Exports and Domestic Consumption

At New York, Philadelphia, Baltimore, Cleveland, and Whiting, crude oil was refined into finished products including kerosene (used for home lighting), naphtha products (used as cleaning solvents and for making manufactured gas) and lubricants (used in machinery). From the refineries, these products were then distributed to consumers in America and internationally on railroads and ships.

¹⁹ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 627. Original data from: Hidy and Hidy, *History of Standard Oil Company (New Jersey): Pioneering in Big Business, 1882-1911*, 100-01, 120; Industrial Commission, "Preliminary Report on Trusts and Industrial Combinations," I, 541-42; House of Representatives, "Report on Investigation of Trusts," 424, 438-40. Data also collected from the trade journals *Petroleum Age* and *Oil Paint & Drug Reporter*.

The data describing the distribution of refined oil products from the refinery to the end consumer are spotty and the patterns can only be described with broad brushstrokes. Most of the kerosene was exported overseas, with the bulk being consumed in Europe. Domestic consumers used most of the naphtha products and lubricants. Kerosene was sold throughout America, although its use was most common in cities.

Oil Exports

American refiners began to develop international markets for refined oil almost immediately. Fortunately for the historian, exports were documented much more carefully than domestic consumption because port officials had to tabulate tariffs and therefore tracked shipments. This allows us to recreate a pretty complete picture of oil flows internationally, at least from the United States to the major distribution points in various countries around the world.

Bulk shipments of refined oil began in 1861. The firm of Peter Wright & Sons chartered the sail ship *Elizabeth Watts* to deliver kerosene to London in wooden barrels. Apparently, sailors' concerns about the danger of transporting such a flammable substance made it difficult to attract a crew: "Failing to engage sailors in the regular way, men were got aboard while under the influence of liquor, and she sailed down the Delaware River with a drunken crew."²⁰ By the end of the Civil War, trans-Atlantic shipments of refined oil were commonplace. In 1863, a British shipyard built the *Atlantic*, reportedly the first ship with large partitioned containers inside the hull to hold

²⁰ For information on early oil shipments see: James Dodds Henry, *Thirty-Five Years of Oil Transport; the Evolution of the Tank Steamer* (London: Bradbury, Agnew, & Co., 1907), 5.

oil in bulk. Over the next fifteen years, wooden sailing vessels with wood or iron tanks in their hulls transported the bulk of oil abroad. By replacing wooden barrels with large tanks, these vessels decreased the amount of oil lost to leakage and increased the efficiency with which their cargo could be loaded and unloaded. In 1880, Dutch shipyards pioneered the development of tank steamers which eventually handled most of the trade.²¹

By 1866, over two-thirds of the oil refined in America was being exported (Table 4.4). There were also some exports of crude oil, naphtha, lubricants, and residuum, but illuminating oils (mostly kerosene) represented the large majority of overseas shipments (Table 4.5). The large majority of oil exports went to Europe, typically at a rate of between 80 to 90 percent between 1860 and 1900 (Table 4.6).²² Germany and Britain absorbed the greatest amounts of refined oil while France imported the largest quantities of crude oil.²³ However, petroleum exports were not limited to Europe. As early as 1874, refined oil was shipped to China, Japan, Turkey, Australia and numerous other countries throughout the world. If a port had any significant international trade, it was likely that it was receiving American oil by the 1870s.

²¹ Ibid., 6-9.

²² Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, Appendix D:1, 742.

²³ France erected high tariffs on imports of refined oil and low tariffs on crude oil in order to support its domestic refining industry. Ibid., 327.

Table 4.4: Oil Exports, in 1000s of Barrels, 1862-1870²⁴

Year	Total refined output	Domestic consumption	Exported	% Exported	% of Exports of refined vs. crude oil
1862	335	240	95	28	34
1863	855	350	505	59	71
1864	1,266	722	544	43	70
1865	1,336	727	609	46	82
1866	2,049	633	1,416	69	84
1867	2,418	773	1,545	64	92
1868	3,410	1,131	2,279	67	92
1869	3,267	1,089	2,177	67	86
1870	3,875	1,292	2,583	67	90

Table 4.5: Oil Exports, in 1000s of Gallons, 1871-1900²⁵

Year	U.S. crude production	Crude exports	Illuminating exports	Naphtha exports	Lubricant exports	Residuum exports	Total exports
1871	218,620 (5,205 bbls)	11,279 (\$2,172)	132,179 (\$33,493)	8,399 (\$896)	240 (\$92)	101 (\$10)	152,197 (\$36,664)
1875	510,826 (12,163 bbls)	16,537 (\$1,739)	201,679 (\$28,169)	14,049 (\$1,392)	938 (\$266)	2,324 (\$170)	237,526 (\$31,735)
1880	1,104,017 (26,286 bbls)	36,748 (\$2,772)	286,132 (\$29,048)	15,115 (\$1,345)	5,607 (\$1,142)	3,178 (\$199)	346,779 (\$34,506)
1885	918,069 (21,859 bbls)	81,436 (\$6,041)	445,881 (\$39,476)	14,739 (\$1,161)	12,979 (\$2,659)	5,714 (\$335)	560,784 (\$49,672)
1890	1,924,552 (45,823 bbls)	96,573 (\$6,535)	550,878 (\$39,826)	12,463 (\$1,051)	32,091 (\$4,767)	1,831 (\$92)	693,830 (\$52,271)
1895	2,221,476 (52,892 bbls)	111,285 (\$5,162)	714,859 (\$34,707)	14,801 (\$911)	43,419 (\$5,867)	138 (\$13)	884,502 (\$46,660)
1900	2,672,062 (63,621 bbls)	137,501 (\$7,310)	730,585 (\$53,934)	18,263 (\$1,648)	68,998 (\$9,543)	19,776 (\$842)	975,123 (\$73,276)

²⁴ Ibid., 332, 325, 332, 338, Appendix A.²⁵ United States Geological Survey, *Mineral Resources of the United States, 1901*, 540-42. The value of the exports, in \$1,000 increments, is noted in parentheses.

Table 4.6: Oil Exports by Destination, in 1000s of Gallons, 1874²⁶

Region	Crude Oil	Naphthas	Illuminants	Lubricants	Residuum
Europe	16,875.5 (\$1,996.2)	9,655.2 (\$1,018.6)	194,434.0 (\$32,564.7)	1,166.1 (\$366.9)	36.2 (barrels) (\$124.9)
North America	899.0 (\$141.3)	59.8 (\$25.6)	4,680.0 (\$1,074.2)	38.3 (\$20.2)	5.9 (barrels) (\$12.5)
South America	1.8 (\$.2)	14.1 (\$3.8)	4,601.6 (\$1,021.2)	27.6 (\$13.0)	1.5 (barrels) (\$4.9)
Asia	...	7.2 (\$2.0)	6,406.2 (\$7)	.7 (\$.3)	...
Oceania	...	...	3,754.1 (\$828.6)	...	...
Africa	...	1.0 (\$.2)	2,674.5 (\$578.9)	11.6 (\$3.8)	...
All other ports, countries, seas	...	...	670.2 (\$135.7)		
Total	17,776.4 (\$2,107.8)	9,737.5 (\$1,050.2)	217,220.5 (\$37,620.8)	1,244.3 (\$404.2)	43.5 (barrels) (\$142.3)

The demand for illuminating oil in foreign markets was driven by several factors, most significantly price. The alternatives to kerosene were either much more expensive (whale oil), offered inferior light (candles), or were not available to most of the population (gas light). These problems were particularly acute in continental Europe because those nations had been experiencing shortages of fats and oils for several decades that increased the price of candles.²⁷ As many parts of Europe experienced the connected processes of industrialization and urbanization, this also increased the need for better lighting in factories and homes.

Petroleum exports became one of the United States' most valuable products by the 1870s (Table 4.7). While cotton remained the nation's most lucrative export product, petroleum ranked fourth overall, and first in terms of manufactured goods. Oil exports,

²⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, Appendix D, 742-43. The value of the exports, in \$1,000 increments, is in parentheses.

²⁷ Ibid., 322.

therefore, played an important role in the rise of the United States' position in the global economy during the latter half of the nineteenth century.

Table 4.7: Average Annual Value of U.S. Exports, in Millions of Dollars, 1871-1900²⁸

Years	Cotton	Wheat	Meat	Petroleum
1871-75	\$205.6	\$82.2	\$33.9	\$36.9
1876-80	183.5	134.0	66.7	43.8
1881-85	218.8	157.6	69.3	47.8
1886-90	224.6	106.3	59.7	51.2
1891-95	230.7	147.2	82.2	49.3
1896-00	220.9	148.2	100.9	68.8

Domestic Consumption

The patterns of oil flows from the refineries to consumers within the United States are extremely difficult to trace. From about 1860 to 1880, jobbers purchased oil products from the refineries and then distributed them to local stores using railroads and wagons. Local stores sold oil from barrels to consumers in gallon increments. In this sense, the flows of oil from refineries to consumers were similar to the distribution of a wide range of consumer goods in the nineteenth century. Unfortunately, comprehensive data tracing the sales of oil from these county stores is lacking. Even Stephen Peckham, who spent several years studying all aspects of the oil industry on behalf of the Census, bemoaned the lack of concrete data on domestic consumption, stating: “[t]he amount of petroleum and petroleum products consumed in the United States in any given time is a residual quantity consisting of elements very difficult to estimate with absolute accuracy.”²⁹

Williamson and Daum argue that between 1865 and 1873, domestic consumption was predominantly an urban phenomenon and that it was centered in the mid-Atlantic

²⁸ Department of Commerce, "Statistical Abstract of the United States, 1946," (Washington: 1946), 904, 905.

²⁹ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 270.

states. Some oil went to the south, but the devastating effects of the Civil War on southern railroads limited the penetration because it increased the transport price and made certain areas difficult to reach. Oil marketers found better success in the mid-West, where the region's transport infrastructure remained in better condition.³⁰ Over the next decade, they note that urban markets still dominated domestic consumption. It was in cities that people had greater needs for improved lighting and large quantities of naphtha were sold to urban gas works. While country stores generally stocked kerosene for consumers by the 1870s, it was often considered a luxury purchase rather than a requirement for people living in rural areas.³¹

By the beginning of the 1880s, Standard Oil had begun to take control over the marketing of oil as well its transport and refining. Their key innovation was to establish a system of marketing stations and tank wagons to supply general stores with oil to sell to consumers. Each marketing area had one or more main stations surrounded by several substations. The main station had large storage tanks with a capacity of 5,000 to 10,000 barrels, roughly equal to a 30 to 60 day supply. The tanks were supplied by shipments of refined oil by railroad tank cars from the refineries. Depending on the population density and size of the marketing area, several substations with storage capacity of 250 to 500 barrels would receive their supplies of oil from the main station and distribute it to the smaller towns in the countryside. From either the main station or the substation, an employee would drive a tank-wagon with a capacity of a few hundred gallons to the

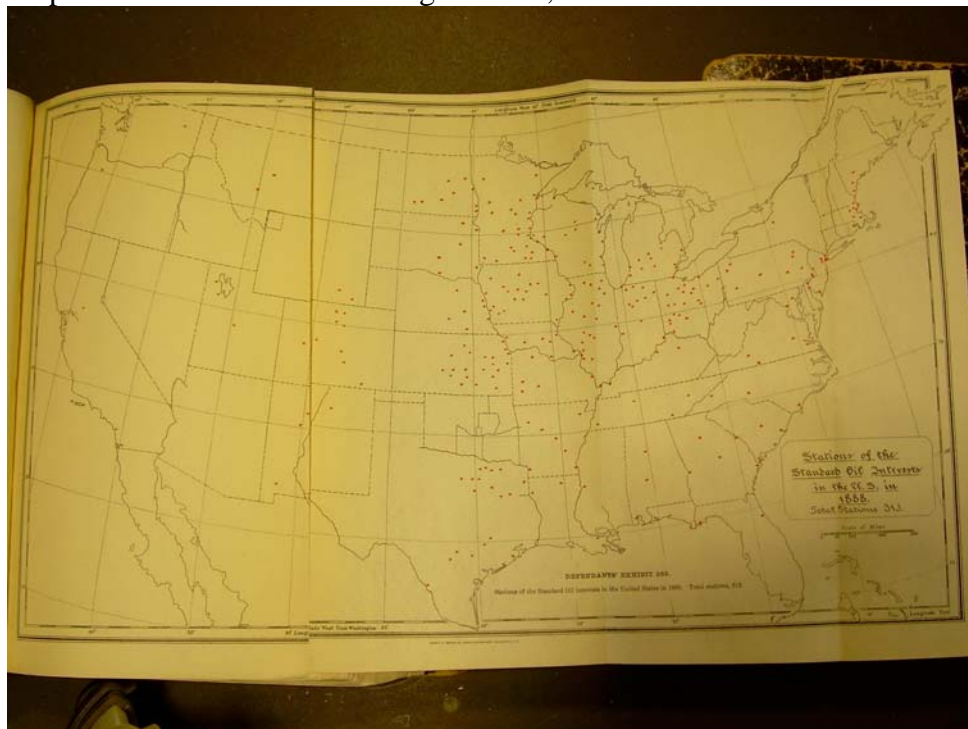
³⁰ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 338.

³¹ *Ibid.*, 524-26.

stores on his route and sell oil to the storekeepers. A tank-wagon driver typically had a range of about twenty miles.³²

By eliminating the jobbers and controlling the output of refined oil, Standard Oil was able to control nearly 90 percent of the marketing of oil in the United States by 1900. Because of John D. Rockefeller's obsessive attention to detail, Standard Oil's Statistical Department kept detailed records on how much oil was sold, where it was sold, and how much market share competitors had in any given area. However, because Standard Oil also prized its secrecy, most of these documents were either destroyed or never made available. The only public records of this information that I have discovered are the documents that were obtained under subpoena in the famous antitrust case that began in 1906. Two pieces of information are particularly illustrative. The first is a set of maps showing the growth of the Standard Oil marketing stations between 1888 and 1906.

³² Details on the operations of the Standard marketing system are given in the testimony of Standard officials in the *United States v. Standard Oil of New Jersey* antitrust case. See, in particular, the testimony of William King, John Archbold, and Henry Tilford in: *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants*, vol. 12, vol. 17, vol. 17.

Map 4.4: Standard Oil Marketing Stations, 1888³³Map 4.5: Standard Oil Marketing Stations, 1906³⁴

³³ Ibid., vol. 19, Defendant's Exhibits, Exhibit 263, p. 622.

³⁴ Ibid., vol. 19, Defendant's Exhibits, Exhibit 264, p. 623.

These maps demonstrate that by the turn of the twentieth century, Standard Oil had established marketing stations near every settled population, even including a few stations in Alaska. Practically every community of any size in America had access to kerosene through a Standard Oil affiliate. For example, Standard Oil's marketing stations in 1904 served towns in Colorado with as few as 200 residents.³⁵ But neither population nor marketing stations were distributed evenly. The densest concentration of marketing stations in 1906 started along the middle of the eastern seaboard and extended through the industrial core of Pennsylvania and Ohio. This was not by accident. If we were to superimpose the map of pipelines circa 1900, we would see that its outlines mirrored this geography closely.³⁶ While oil was available everywhere, the marketing stations were disproportionately located in the mid-Atlantic.

In addition, by comparing the sales of oil in various geographic regions by Standard Oil and its competitors, we can see the disproportionate sales of oil in mid-Atlantic cities (Table 4.8). Philadelphia, New York City, and Baltimore each consumed more oil than either the state of Ohio or California. Residents of the New York City and Newark purchased a greater amount of illuminating oils and naphtha products than the rest of New York state as well as the entire St. Louis region comprising the part of Illinois near St. Louis, the southern half of Missouri, Arkansas, Indian Territory, Oklahoma, Texas, Louisiana west of the Mississippi, and Mexico.

³⁵ Standard Oil had marketing stations in towns such as Fort Lupton, CO (population 214), Eaton, CO (population 384), and Breckenridge, CO (population 976). *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants: Brief for Defendants on Facts*, 3 vols. (N.P.: [1909]), vol. 3, p. 576. Note: this volume was filed in conjunction with the *United States v. Standard Oil of New Jersey* case but its title pages do not identify an exact date or place of publication.

³⁶ See Map 4.2 earlier in the chapter. Both maps show a rough rectangle bordered by Chicago on the northwest, Albany on the Northeast, extending south through New York City and Philadelphia to Baltimore on the Southeast corner, and continuing west from Baltimore through Pittsburgh and the middle of Ohio.

Table 4.8: Domestic U.S. Consumption of Refined Oil, in Barrels, 1904³⁷

(measures are in barrels)	Illuminating Oil			Naphtha Products		
	Standard	Independent	% Indep.	Standard	Independent	% Indep.
Kentucky	1,269,074	179,845	12.4	516,766	92,689	15.2
Indiana	2,125,164	321,618	13.1	1,348,329	193,316	12.5
St. Louis	771,046	89,453	10.4	278,640	29,850	9.6
San Francisco	388,418	35,467	8.4	245,803	61,636	20.0
Denver	144,521	1,332	.9	44,304	302	.7
Ohio	418,836	68,989	14.1	277,464	18,663	6.3
Winnipeg & Vanc.	66,450	17,697	21.0	10,913	5,123	31.9
General Trade	24,053	893	3.6	11,605	271	2.3
Total West	5,207,562	715,294	12.1	2,733,824	401,850	12.8
Pittsburgh	329,856	71,406	17.8	64,509	16,049	19.9
NY stations	689,669	60,856	8.1	128,275	15,642	10.9
Toronto	173,248	35,061	16.8	28,493	6,311	18.1
Total Middle	1,192,773	167,323	12.3	221,277	38,002	14.7
Baltimore	727,747	70,537	8.8	185,160	23,676	11.3
West India O. Co.	14,619	6,873	32.0	274	...	...
Philadelphia	661,654	91,333	12.1	252,382	38,365	13.2
Providence	538,254	34,726	6.1	136,599	10,830	7.3
Boston	676,970	55,843	7.6	189,339	9,546	4.8
Newark	199,575	21,269	9.6	93,304	12,368	11.7
N.Y.C.	527,816	44,350	7.7	192,911	22,697	10.5
Montreal	105,249	28,323	21.2	13,576	2,679	16.6
Maritime Prov	84,564	14,308	14.5	2,925	154	5.0
Govt. Oil (Canada)	...	2,561	...	...	60	...
Total East	3,536,448	370,145	9.5	1,066,470	120,375	10.1
Unknown		188,177			74,610	
Total	9,936,783	1,440,939	12.7	4,021,571	634,837	13.6
Standard Oil Purchases from independents	113,861	113,861		84,882	84,882	
Grand Total	9,822,922	1,554,800	13.7	3,936,689	719,719	15.5

³⁷ *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants.*, vol. 8, Petitioner's Exhibits, Exhibit 387a, p. 916. Kentucky refers to the Standard Oil Company of Kentucky, which served Louisiana east of the Mississippi River, Mississippi, Tennessee, Kentucky, Georgia, Florida, and Alabama. The Standard Oil Company of Indiana served North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Kansas, northern Missouri, Illinois, Michigan, and Indiana. St. Louis refers to the region of the Waters-Pierce Company, which served the part of Illinois near St. Louis, the southern half of Missouri, Arkansas, Indian Territory, Oklahoma, Texas, Louisiana west of the Mississippi, and Mexico. San Francisco indicates the region of Standard Oil of California: California, Washington, Oregon, Arizona, and Nevada. Denver was served by the Continental Oil Company operating in Colorado, Utah, Montana, Idaho, Wyoming, and New Mexico. Ohio was served by the Standard Oil Company of Ohio, Pennsylvania and Delaware were served by the Atlantic Refining Company, while the Standard Oil Company of New York served New York and the New England states. Finally, the Standard Oil Company of New Jersey supplied oil to North Carolina, South Carolina, Virginia, West Virginia, Maryland, and New Jersey. Winnipeg, Vancouver, Montreal, Toronto, and Maritime Provinces represent the sales in Canada.

While the mid-Atlantic led the nation in oil consumption, it is important to note that the distribution of petroleum products was national in scope, especially when compared to the limited distribution of anthracite coal in the antebellum period. Two factors shaped the broad geography of oil consumption. First, between 1860 and 1900 the development of a railroad network across the continental United States made it possible for goods to be shipped overland much more cheaply than was possible before the Civil War. Second, consumers could benefit from purchasing much smaller quantities of kerosene than anthracite coal. A single gallon of kerosene could provide up to 140 hours of light—enough to give a family an extra hour and a half of light per night for an entire season.³⁸ By contrast, a family purchasing anthracite coal would need to purchase several tons every winter to stay warm. Therefore, kerosene purchases represented a much smaller fraction of a family's overall budget, bringing it within the financial reach of a much wider range of the public.³⁹

In reviewing the flow of petroleum from the Oil Regions to refineries and then to consumers, three patterns are particularly important. First, transport infrastructure networks shaped the distribution of crude oil. The energy landscapes of waterways, railroads, and pipelines structured where oil went, thereby favoring certain places over others. Second, refined oil was sold across the nation, even as far away as Alaska. This development was also dependent on transport infrastructure—the creation of a vast web

³⁸ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 496.

³⁹ The price of kerosene will be discussed further in the next section. By the last decade of the nineteenth century, a gallon of kerosene was selling for eight to ten cents wholesale in cities such as New York, and its actual cost to consumers was somewhat higher. Even at thirty cents a gallon, it was much cheaper for a family to purchase a gallon of kerosene than a one or two month supply of anthracite coal.

of railroad lines over the latter half of the nineteenth century made it possible for refined oil to be distributed practically anywhere people were living. However, the extent to which different areas were served by competitive transport system influenced the cost at which refined oil was available. In other words, oil flowed almost everywhere, but not in the same quantities or at the same price. Third, the mid-Atlantic was the center of America's production, refining, and consumption of crude oil during the nineteenth century. New York and Philadelphia led the nation in refining while the consumption of petroleum products in eastern seaboard cities outpaced its use in other areas.

Consuming Oil, Deepening the Mineral Economy

The first forty years of the petroleum industry had profound consequences for the environment, economy, and development of the mid-Atlantic. It created massive wealth, particularly for Standard Oil executives. Standard Oil's monopoly powers ultimately provoked one of the most significant antitrust cases in the nation's history. The production and refining of oil remade the landscape of western Pennsylvania and the mid-Atlantic.

Oil also accelerated the transition from the organic to the mineral economy in the mid-Atlantic region. It provided a new form of fossil fuel energy that could be used to generate light, lubricate machinery, create heat, and be processed into a variety of products like solvents, waxes, and tar. This section documents the various uses of petroleum between 1860 and 1900 and analyzes the ways these patterns deepened the transition to a mineral economy. I also note two additional developments of particular

importance in understanding the shift away from organic energy sources. First, oil's most significant effects on the creation of a mineral economy began in the nineteenth century but only achieved full expression after the turn of the twentieth century with the expanded use of fuel oil and gasoline. Second, coal provided the bulk of fossil fuel energy consumed in the mid-Atlantic during the latter half of the nineteenth century. Therefore, to understand the expansion of the mineral economy, it is necessary to review the expansion of coal consumption from 1860 to 1900.

Table 4.9: U.S. Refinery Output, 1000s of Barrels, 1873-1899⁴⁰

	1873-1875 (average)	1878-1880 (average)	1884	1889	1894	1899
Illuminating Oil						
Production	6,529.5	10,779.8	15,450.4	20,191.2	29,457.5	29,953.8
% of Refined Output	85.4	85.3	80.0	74.4	70.0	61.2
Domestic Consumption	1,626.0	3,197.1	5,120.6	7,053.8	12,067.8	12,702.3
Exports	4,903.5	7,602.7	10,329.8	13,137.4	17,389.7	17,251.5
% Exported	75.1	70.4	66.9	65.1	59.0	57.9
Naphtha-Benzine-Gasoline						
Production	894.7	1,482.2	2,485.1	3,915.6	6,113.9	6,682.5
% of Refined Output	11.7	11.7	12.9	14.4	14.4	13.7
Domestic Consumption	617.6	1,100.7	2,159.5	3,582.6	5,743.5	6,256.2
Exports	277.1	381.5	325.6	333.0	370.4	426.3
% Exported	31.0	25.7	13.1	8.5	6.1	6.4
Lubricating Oils						
Production	225.8	376.1	898.7	1,834.5	3,288.4	4,056.6
% of Refined Output	3.0	3.0	4.7	6.8	7.8	8.3
Domestic Consumption	198.6	286.4	613.3	1,170.1	2,331.5	2,405.9
Exports	27.2	89.7	285.4	664.4	956.9	1,650.7
% Exported	12.0	23.8	31.8	36.2	29.1	41.7
Fuel and Residuum						
Production			482.9*	1,195.0	3,522.0*	8,239.1
% of Refined Output			2.5	4.4	8.3	16.8
Domestic Consumption			482.9	1,195.0	3,552.0	8,239.1
Exports			0	0	0	0
% Exported			0	0	0	0
Total Refined Output	7,650.0	12,638.1	19,317.1	27,136.3	42,381.8	48,932.0

⁴⁰ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 485, 678. Data from: Bureau of Corporations, *Report of the Commissioner of Corporations on the Petroleum Industry*, 3 vols. (Washington: Government Printing Office, 1907), II, Table 24:1, p. 231; *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*; United States Geological Survey, *Mineral Resources of the United States, 1904* (Washington: Government Printing Office, 1905). An asterisk (*) indicates an estimated value.

Illuminating Oils

The illumination market was the primary driver for the beginning of the oil industry. The first major report on the chemical characteristics of petroleum by Benjamin Silliman focused on lighting and it was illumination that attracted investors.⁴¹ The prospectus for the Cherry Run Petroleum Company in 1863 enthusiastically claimed: “Petroleum is bound to become the *illumination* of the world.”⁴² The market for illuminants showed great promise both because of limited supplies from other sources and the increasing demand for light from an urbanizing and industrializing population. Throughout the nineteenth century, illuminating oils were the main output of American refineries, representing as much as 85 percent of the total in 1873-75 and 70 percent in 1894 (Table 4.9).

Before the introduction of kerosene, Americans had used a wide range of illuminants including candles, whale oil, camphene, coal oil, and manufactured gas. Candles were the most common form of artificial lighting before 1830. They were relatively cheap and easy to make, particularly for a rural population with farm animals (a wick dipped into fat or tallow would produce a flame). Whale oil, particularly from sperm whales, provided a much brighter glow, but was more expensive. By the 1840s, camphene, a mixture of turpentine and alcohol, became the most commonly used synthetic illuminating liquid in America. Coal was also used to create artificial light. In response to developments in Europe, the United States developed a coal-oil industry in

⁴¹ The subtitle of Silliman’s report, “With special reference to its use for illumination and other purposes” indicates the importance of lighting for early oil advocates. Silliman, *Report on the Rock Oil, or Petroleum, from Venango Co., Pennsylvania: With Special Reference to Its Use for Illumination and Other Purposes*.

⁴² *The Cherry Run Petroleum Company, Venango County, Pa.* (Philadelphia: Printed for the Company by J. Richards, 1863), 23. Italics are in original text.

the 1850s. Building on the success of Europeans, by 1860 American firms were producing as much as 30,000 gallons of coal-oil a day and selling it at wholesale for 75 cents a gallon.⁴³ In addition, wealthy residents of cities could obtain light from manufactured gas companies. By the 1850s, urban gas works piping manufactured coal gas into people's homes were operating in more than 50 American cities.⁴⁴ Finally, electric lighting, pioneered by Thomas Edison in 1882, provided another source of fossil-fuel based lighting.

However, none of these alternatives possessed the combination of widespread availability, cheapness, and quality of light of kerosene. Candles offered a comparatively weak glow. The superior light of whale oil came at a price—between 34 and 79 cents a gallon at wholesale between 1846 and 1856 while the more highly desired sperm oil cost between 88 cents and \$1.62 per gallon in the same period.⁴⁵ Camphene offered comparable light quality to whale oil but it gave off a foul smell and was prone to dangerous explosions. Moreover, its cost often ran as high as \$2.00 a gallon depending on where it was delivered.⁴⁶ The coal-oil industry was entirely subsumed by the petroleum industry within a few years as coal-oil refiners discovered it was much cheaper to make illuminating oils with petroleum than coal.⁴⁷ And the benefits of manufactured gas and electricity were restricted to the homes of wealthy urban residents because of the high costs for installing pipes and wires as well as expensive monthly service charges.

⁴³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 56-58.

⁴⁴ *Ibid.*, 39.

⁴⁵ Walter Sheldon Tower, *A History of the American Whale Fishery* (Philadelphia: University of Pennsylvania Press, 1907), 52.

⁴⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 33-34.

⁴⁷ For example, the three coal-oil refining firms in Pittsburgh—the North American, Lunesco, and Alladin companies—had converted to petroleum as their raw material by 1861: Thurston, *Pittsburgh and Allegheny in the Centennial Year*, 203.

By contrast, kerosene offered a high-quality illuminating fuel that was cheaper than its competitors and required minimal investment by consumers. In 1865, a gallon of kerosene cost 72 cents (wholesale in New York). By 1870, the price had dropped to 26 cents and to 8 cents in 1885.⁴⁸ Typically, consumers paid 10 to 15 cents per gallon at the store for kerosene over the last two decades of the nineteenth century, depending on how far they were located from a major refinery or marketing station.⁴⁹ In addition, there were few barriers preventing consumers from switching to kerosene. In the 1850s, the coal-oil industry had introduced low-cost lamps into markets (often less than a dollar) and taught consumers how to tend wicks and maintain their lights.⁵⁰ It was simple and cheap, therefore, for consumers to begin using kerosene.

The introduction of kerosene into lighting markets did face other barriers, particularly the danger of fire. Many cities passed zoning restrictions and inspection laws that limited the areas where large amounts of oil could be stored and specified fire safety standards.⁵¹ These requirements also led to the creation of various grades of kerosene according to two main variables. The first was the color and appearance of the oil

⁴⁸ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 326, 524.

⁴⁹ *United States of America, Petitioner, V. The Standard Oil of New Jersey Et Al, Defendants: Brief of Facts and Argument for Petitioner*, 2 vols. (N.p., [1909]), vol. 2, p. 8-12.

⁵⁰ The coal-oil industry also paved the way for the development of petroleum refining because most of the skills and technologies used to manufacture illuminating oils from coal were applicable to crude oil as well. Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 57-58.

⁵¹ For example, in 1865 Philadelphia passed a law titled "An Act for the better security of the City of Philadelphia from dangers incident to refining or improper and negligent storage of Petroleum, Benzine, Benzole or Naphtha." In 1868, Philadelphians petitioned the Governor to pass an act that forbid oil which ignited at temperatures below 110 degrees from entering the city's boundaries. In New York, the City Board of Fire Underwriters published report offering their recommended policies on the handling of petroleum products. License of Compliance, "Business Papers and Agreements and Contracts, 1881-1892," Malcolm Lloyd Papers, Collection 1990, Historical Society of Pennsylvania, Philadelphia, PA. *An Act Authorizing the Governor of the Commonwealth to Appoint an Inspector of Refined Petroleum, Kerosene, and Burning Oils, in and for the City and County of Philadelphia*, (S.L., 1868); *Report of the Committee on Gas Machines, Carbureters, and the Handling and Using of the Lighter Products of Petroleum, Made to the New York Board of Fire Underwriters and Adopted October 29, 1860*, (New York: Wm. H. Woglom & Reading, Printers, 1869).

(standard, water white, and premium). The second category was the fire test, which determined the temperature at which the oil would ignite.⁵² Most often, explosions were caused when lighter, more inflammable, naphtha fractions were mixed in with kerosene or when the refining of the oil was not complete. While the classifications of kerosene and fire tests helped improve safety, it did not solve the problem. A trade journal reported that between 5,000 and 6,000 people died annually during the 1870s as a result of fires started by exploding lamps.⁵³

Despite the risk of fire, kerosene was by far the most widely used oil product of the nineteenth century both domestically and internationally (Table 4.9). Its use contributed to two shifts in the development of a mineral economy: first, it was an artificial lighting source that could be produced and consumed on an exponentially increasing basis. Second, it led to cultural shifts away from the natural patterns of the seasons.

Kerosene's output could be continually expanded as long as more oil fields were discovered. Candles, whale oils, and camphene, by contrast, all faced finite limits to the expansion of their production characteristic of the organic economy. The decline in candle production due to a shortage of fats and tallow in continental Europe during the nineteenth century indicated the connections between candles and the land. The same was true for camphene, whose main ingredient, turpentine, came from resin-bearing trees. And despite the common rhetoric of the inexhaustibility of the oceans, whaling vessels

⁵² The first person to develop metrics for a fire test was said to be Hon. Zachariah Allen of Providence, Rhode Island, who suggested this approach in an article in *The Report of the Smithsonian* in 1862. Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 214-15.

⁵³ *Oil, Paint & Drug Reporter*, Nov. 21, 1881, 901-2. Cited in: Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 524.

were already being forced to travel longer distances in search of prey by the 1860s.

The output of the American industry actually peaked in 1846, years before the introduction of petroleum illuminants.⁵⁴ It is doubtful that the oceans could have continued to provide American consumers with average yields of 117,950 barrels of sperm oil and 215,913 barrels of whale oil, as the industry had produced between 1835 and 1860.⁵⁵ While petroleum has rightly been linked with numerous environmental harms, kerosene most likely saved certain species of the world's whale populations from extinction.

Coal oils, manufactured gas, and electricity were not subject to these same limits because they were based on fossil fuels. However, they had other limitations. Coal oils were much more expensive than kerosene, while both manufactured gas and electricity were expensive and only available in limited geographic areas.⁵⁶ During the nineteenth century, most of their light was limited to factories, streetlights, and the homes of the urban wealthy.

Kerosene, therefore, offered a form of fossil fuel based lighting that was broadly available and not subject to limits. As with other forms of fossil fuel energy, once people got access to it, their appetite increased quickly. The average American per capita consumption of kerosene was 1.5 gallons in 1874, 3.6 gallons in 1884, and 7.4 gallons in

⁵⁴ Tower, *A History of the American Whale Fishery*, chapter 6.

⁵⁵ *Ibid.*, 52.

⁵⁶ It is possible that illuminants produced from coal could have become cheaper over time with improved technologies and processes. However, the introduction of petroleum ended much of the research into coal oil development. In the absence of further data, we have little reliable evidence on what the price of coal oils would have been had petroleum not overtaken the market. However, given the difficulties still being experienced by Germany during its synthetic fuel experiments with coal several decades later during World War II, it seems reasonable to assume coal oils would not have been as cheap as petroleum-based illuminants. In addition, as will be discussed in the next section, most manufactured gas was produced with naphtha beginning in the 1870s, so this lighting system was soon dependent on petroleum as well.

1894.⁵⁷ As a gallon of kerosene could provide about 140 hours of light, this represented an increase from 210 to 1,036 hours of light a year, or about 40 minutes a day of lighting to nearly 3 hours.⁵⁸ Given that more petroleum was consumed in the mid-Atlantic than any other part of America, the per capita consumption in the region was even more extensive than these numbers indicate.

The widespread consumption of kerosene also contributed to cultural shifts associated with new lighting patterns. People living in an organic economy tend to experience the changes in nature more directly than those in a mineral economy. Two of the most important environmental changes are the shifts between day and night and the seasonal pattern of longer days in the summer and longer nights in the winter (in the northern hemisphere). With lighting a limited and somewhat expensive resource, this encouraged certain patterns of social behavior. Gatherings in the evenings, for example, were often held during times of the month where the moon was full thereby making night travel easier and safer.⁵⁹ If manufacturing operations did not have artificial lighting in winter months they needed to close their doors early.⁶⁰ Those living on farms often slept much longer hours during winter as a result of having less work and less light.⁶¹

Kerosene helped change these patterns, reflecting a move away from the organic. Quite literally, kerosene helped many to lengthen the day.⁶² With cheap and abundant light, it was easy for people to have social gatherings in the evenings, do detailed work at

⁵⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 521, 681.

⁵⁸ *Ibid.*, 496.

⁵⁹ Brian Bowers, *Lengthening the Day: A History of Lighting Technology* (Oxford: Oxford University Press, 1998), chapter 2.

⁶⁰ Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 97.

⁶¹ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 30.

⁶² Bowers, *Lengthening the Day: A History of Lighting Technology*.

home, or spend more time reading. Factories could employ either kerosene lamps or manufactured gas to extend hours during the winter. As a kerosene booster reported to *Chemical News*: “[t]he effect that this illuminating agent has produced throughout the country is very striking. It has entirely displaced all other means of lighting except gas, and is used even in cities by many who desire an absolutely steady light... Kerosene has, in one sense, increased the length of life among the agricultural population. Those who, on account of the dearness or inefficiency of whale oil, were accustomed to go to bed soon after sunset and spend almost half their time in sleep, now occupy a portion of the night in reading and other amusements; and this is more particularly true of the winter season.”⁶³ While a more cautious observer might not have ventured such a bold declaration as early as 1864, Dr. Draper’s statement captures a gradual change in people’s living patterns that occurred over the course of the next several decades.

Naphtha Oils

Naphtha oils were the lightest fractions of refined crude oil, including naphtha, benzine, and gasoline.⁶⁴ Because kerosene was the most desired output, refiners tried to minimize the output of naphtha oils to a little over 10 percent of the total crude oil processed.⁶⁵ At first, these lighter fractions were difficult to sell because there were few known applications and their volatility made them dangerous for general use. Often they

⁶³ Quotation reprinted in Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 261. Original quotation appeared in *Chemical News*, 1864, x, 204.

⁶⁴ During refining, when crude oil is subjected to heat, the lighter fractions such as naphtha, benzine, and gasoline were drawn off first. The various grades of kerosene represented the middle fractions, and the heavier fractions were used to manufacture lubricants and residuum.

⁶⁵ United States Geological Survey, *Mineral Resources of the United States, 1901*, 540. When gasoline, which is a lighter fraction of crude oil, became the dominant refinery output in the twentieth century, refiners altered their techniques to greatly increase the percentage of gasoline produced while correspondingly reducing the middle fractions previously used for kerosene.

were simply burnt off as a valueless by-product similar to the way early drillers in Texas flared natural gas. Occasionally, unscrupulous refiners mixed naphtha oils into kerosene, contributing to the fires resulting from exploding lamps. However, by the end of the period, several new uses for naphtha had been found, and it began to be sold at a price similar to kerosene. The result was a small increase in the percentage of oil refined into naphtha fractions from just over 11 percent in 1873 to nearly 15 percent by 1899 (Table 4.9).

The first widespread use for naphtha and benzine was in cleaning solvents, particularly for working with India rubber or gutta percha used in waterproofing. Benzine could also be used to extract oils from vegetable materials such as flax, cotton, and castor beans.⁶⁶ Other applications of naphtha included replacing turpentine in the manufacture of varnishes and lacquers as well as cleaning guns and oil wells.⁶⁷

The biggest boost to the naphtha industry during the nineteenth century was its application to the manufacture of gas for lighting systems. For years, urban gas works had used bituminous coal to generate their gas. In 1869, A. C. Rand and Dr. Leonard Gale revolutionized the industry by developing a process to make manufactured gas with naphtha. They demonstrated that naphtha could provide a comparable quality gas while lowering the cost of labor and materials by as much as two-thirds. Within four years, at least fourteen gas companies were using naphtha exclusively to produce manufactured gas.⁶⁸

⁶⁶ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 234.

⁶⁷ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 260.

⁶⁸ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 238-240.

Gasoline, the quintessential petroleum product of the twentieth century, was mostly considered a low-value byproduct in the nineteenth century. Air-gas machines used gasoline to produce light but this did not constitute a large market.⁶⁹ A few automobiles with internal combustion engines were introduced in the 1890s, but there were only 8,000 automobiles registered in the United States in 1900. Therefore, neither gasoline nor other naphtha oils contributed greatly to the emergence of a mineral economy in the mid-Atlantic during the nineteenth century. However, as will be discussed later in this section, gasoline had revolutionary effects as automobile use expanded in the early decades of the twentieth century. By 1912, the number of car registrations had grown to more than 900,000, creating new demands for petroleum.⁷⁰

Lubricants

Although lubricating oils represented only a small percentage of the overall consumption of petroleum during the nineteenth century, they were arguably the most important product of rock oil. Lubricants derived from animals and plants had greased axles, waterwheels, and other moving parts in machinery for thousands of years. However, with the application of steam power to machinery and vehicles, the levels of friction and resistance grew exponentially over the course of the nineteenth century. As energy analysts have noted: “[b]y the middle of the nineteenth century, the rapid growth of the factory system, the invention of new machines, and the expansion of steamship and railroad transportation had reached the point where the scarcity of efficient lubricants had

⁶⁹ Ibid., 235.

⁷⁰ Car registration numbers from Yergin, *The Prize: The Epic Quest for Oil, Money, and Power*, 80.

become a serious bottleneck.”⁷¹ After about a decade of experimenting with new techniques like slow distillation, refiners learned to make high quality lubricants out of petroleum. The chemical properties of these new products ensured that friction would not slow the accelerating pace of industrial growth.⁷²

Whereas kerosene was sold in just a few grades, refiners created dozens of varieties of lubricants. This diversification was a response to the very different needs of machinery: some required heavy lubricants that could withstand high heat while others benefited from a higher-viscosity oil. A particular type of lubricating oil manufactured by the Galena-Signal Oil Company (a company eventually purchased by Standard Oil) was so effective under heat and pressure that it was eventually used by over 95 percent of the nation’s steam railroads.⁷³ An 1878 analysis of lubricating oils found over 118 varieties, of which the most common classes were spindle oils, machine oils, and cylinder oils.⁷⁴ Because several lubricants were specialized products instead of commodity goods like kerosene, this market offered opportunities for small refiners to maintain profitable businesses and avoid direct competition with Standard Oil.

The geography of oil influenced the production of lubricants. In general, Pennsylvania’s crude oil production was characterized by high levels of paraffin wax, which were helpful in the manufacture of certain lubricants. However, certain oil fields contained crude with even higher levels of heavy oils. The “Venango first sand” of the Franklin field, about fifteen miles southwest of Titusville, produced the best oil for

⁷¹ Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 99.

⁷² *Ibid.*, 100.

⁷³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 244.

⁷⁴ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 195-96.

making lubricants and sold at a much higher price.⁷⁵ Although it is common to think of crude oil as a generic commodity, the particular characteristics of oil fields often influenced refining, particularly in the production of lubricants.⁷⁶

Lubricants enhanced the transition to the mineral economy by literally greasing the joints of the mid-Atlantic's industrial machinery. Their importance, in this respect, far outweighed their meager percentage of total output (never more than 10 percent of refinery production). Seince the mid-Atlantic led America's industrialization process, petroleum lubricants played a key role in ensuring that the wheels of industry would keep turning. Whether it was steam engines, railroads, or factory equipment, the increasing levels of power and speed embodied in industrial machinery generated new levels of heat and friction. Although plant and animal based lubricants had been in use for hundreds of years, petroleum-based products offered an increased ability to withstand heat, varying levels of viscosity, and the flexibility to be manufactured into several different products. The continued industrialization of the mid-Atlantic during this period owed a significant debt to new lubricants.

Fuel Oil

Fuel oils represented a small, but growing, percentage of petroleum consumption in the nineteenth century. With minimal processing, crude oil could be burnt to provide

⁷⁵ *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, II, 402-04; Henry, *The Early and Later History of Petroleum, with Authentic Facts in Regard to Its Development in Western Pennsylvania*, 474-77.

⁷⁶ The characteristics of oil fields were relevant to the manufacture of kerosene as well. The oil from the highly productive Bradford Field, for example, was considered less desirable because its yield of kerosene was lower than other fields. The high sulfur content of the Lima Fields meant that only as much as 50% of the oil could be refined into kerosene. This gave an impetus to the increased use of fuel oil, as will be discussed in the next section.

heat and power instead of firewood or coal. Boosters were quick to realize this and sought to develop new markets for crude oil as a replacement for wood or coal. In the early 1860s, individuals in the Oil Regions began experimenting with fuel oils and the Federal government in 1862 passed an act allocating funds to explore the use of petroleum to power naval ships.⁷⁷ However, the use of petroleum as a fuel oil was rare in the early decades of the industry, and only expanded in the last twenty years of the nineteenth century.

For some applications, oil was superior to other fuel sources. Because petroleum could be applied steadily, oil-fired furnaces were relatively easy to maintain at a fixed temperature. In addition, liquid oil could be fed into boilers via gravity instead of by human effort. This was seen as a major advantage for naval ships since more of the crew could be at battle stations during combat rather than shoveling coal.⁷⁸ By 1880, it was reported that petroleum had been shown to be usable in steam vessels and railroads.⁷⁹ However, these advantages of oil were generally offset by its significantly higher price. Even at the price of one dollar a barrel, which was considered extremely low by producers, oil still cost much more than coal per unit of heat output.⁸⁰ Therefore, fuel oil was rarely cost-effective for consumers during the nineteenth century: it was typically much more valuable as an illuminant than a source of heat or power.

⁷⁷ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 240.

⁷⁸ The combustibility of petroleum somewhat offset this benefit for naval ships, and it was only after the development of stronger armor that navies began to switch from coal to oil.

⁷⁹ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 249.

⁸⁰ A barrel of Pennsylvania crude had an average heat output of 5,550,000 BTUs while a ton of anthracite coal produced 25,400,000 BTUs. Therefore, five barrels of oil offered the heat equivalent of a ton of coal. Between 1880 and 1900, the average price of anthracite coal was between \$1.41 and \$2.01, making it much cheaper on a per-BTU basis. BTU information from Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 499. Price information from United States Geological Survey, *Mineral Resources of the United States, 1901*, 301.

There were two major exceptions to this rule. First, when the price of oil at the well-head dropped below a dollar a barrel, some of it was likely used as fuel oil in refineries and factories in the Oil Regions where the negligible transport costs made it competitive with coal.⁸¹ Similar to the lack of data on the use of anthracite consumed in steam engines in coal mines, we have very little data on how much fuel oil was actually burnt in the Oil Regions. Some analysts suggest that the reported levels are therefore too low.⁸² The oil produced in Ohio's Lima fields was a second exception. Lima crude had a high percentage of sulfur making it extremely difficult to refine into kerosene. As a result, its price was much lower than Pennsylvania crude and comparable to coal. Before 1890, it sold for as little as fifteen to thirty cents a barrel and around fifty cents a barrel in the 1890s.⁸³ Therefore, large amounts of Lima crude were used as fuel oil, particularly in Ohio, Indiana, and Chicago.

The efforts of nineteenth-century fuel oil investigations would yield fruit in the twentieth century. A series of factors, including the dramatic expansion of crude oil production, the development of oil fields in California at sites where coal was not abundant and cheap, and a naval arms race between Germany, Britain, and the United States caused the use of fuel oil to grow dramatically in the first decades of the twentieth century. In addition, as noted in the previous chapter, pipelines reduced the cost of oil transport, further lowering the cost to consumers. As will be explored briefly in the next

⁸¹ For example, fuel oil at 75 cents a barrel was comparable to coal at \$3.75 per ton. If the oil had low transport costs and it cost a dollar or two to deliver coal, then it would be as cheap to use oil.

⁸² Schurr et al. note that fuel oil could be burnt without entering a refinery, therefore increasing the likely total consumption significantly as output totals were usually measured at refineries. Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 105.

⁸³ Williamson and Daum, *The American Petroleum Industry: The Age of Illumination 1859-1899*, 601. In addition, yields of illuminating oil from Lima crude oil were typically only 45-50%, forcing refiners to develop markets such as fuel oil for the remaining oil.

section, these uses would have revolutionary impacts on American energy consumption patterns in the early twentieth century.

However, as was the case with naphtha oils, the use of crude oil for fuel made only a small contribution to the mid-Atlantic's transition into the mineral economy until after the turn of the twentieth century. The total amount of oil used for fuel in the nineteenth century was quite small, not exceeding 10 percent of refinery output until after 1894. Other energy sources were more important for the mid-Atlantic's energy economy: the approximately eight million barrels of petroleum used for fuel oil in 1899 only contained the energy equivalent of about 1.4 million tons of coal, less than 1 percent of Pennsylvania's anthracite and bituminous production for 1900.⁸⁴

Oil in the Early Twentieth Century

The finding that the use of oil did not cause a dramatic shift in the transition to the mineral economy results from looking at how and where people consumed petroleum during the nineteenth century. If we expand our perspective to the twentieth century, the story changes dramatically. A quick look at oil consumption between 1899 and 1930 shows exponential increases in petroleum use, particularly when transportation replaced illumination as the main consumption sector (Table 4.10).

The most important shift in oil consumption in the early twentieth century was its application to transportation. Railroads, ships, and automobiles consumed oil in exponentially increasing quantities that dwarfed the use of kerosene. For example, in

⁸⁴ The average BTU value of a barrel of Pennsylvania crude oil was about one-fifth of a ton of coal (5,500,000 BTUs per barrel versus 25,400,000 BTUs for a ton of anthracite). See Table 4.11 below for Pennsylvania coal production. BTU values from Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 499.

1889, 20 million barrels of kerosene could supply the entire American market and satisfy the lighting needs of much of Europe (Table 4.9). By 1909, the railroads in the western United States were reportedly consuming this same amount annually.⁸⁵ The great buildup of naval ships by Germany, Britain, and the United States in the pre-WWI era involved a transition to diesel fuel, thereby increasing the demand for fuel oil.⁸⁶ And the expanded use of automobiles, particularly after the introduction of Henry Ford's Model T in 1908 lowered the price of cars dramatically, would lay the stage for the great expansion of gasoline use. After 1909, gasoline consumption increased from less than 13 million barrels to more than 425 million barrels in 1930, a gain of over 3500 percent in two decades. The use of fuel oils and gasoline increased more than fifty- and sixty-fold between 1900 and 1930 while kerosene output did not even double.

Petroleum and internal combustion engines integrated personal mobility with the mineral economy. Like steam vessels in the antebellum era and railroads throughout the nineteenth century, automobiles created new transportation patterns impossible in an organic economy. Individuals could now harness hundreds of horsepower of energy to travel anywhere adequate roads existed. Moreover, petroleum provided a level of energy availability impossible in an organic economy. The 965 million barrels of refined oil in 1930 provided the energy equivalent of a forest five times the state of Pennsylvania.⁸⁷ By

⁸⁵ Ibid., 105.

⁸⁶ Yergin, *The Prize: The Epic Quest for Oil, Money, and Power*, 212.

⁸⁷ 965 million barrels provided 4,825,000 million BTUs (average barrel of oil generates 5,000,000 BTUs) which is equivalent to were equivalent to about 230 million cords of wood (average BTU of 20,960,000 per cord). The sustainable yield of one cord of wood requires 2/3 of an acre (see chapter 2) therefore necessitating approximately 150,000,000 acres, or 234,375 square miles (there are 640 acres in a square mile). As Pennsylvania's area is 46,055 square miles, oil provided the heat equivalent of a forest over five times the state's total area.

1930, therefore, the use of oil had played a critical role in shifting Americans—in the mid-Atlantic and elsewhere—into the mineral economy.

Table 4.10: U.S. Refinery Output, 1,000,000s of Barrels, 1899-1930⁸⁸

Year	Gasoline and naphtha	Kerosene	Fuel oils	Lubricants	Other products	Total
1899	6.7 (14.0%)	30.0 (62.5%)	7.3 (15.2%)	4.0 (8.3%)	n/a	48.0
1904	6.9 (12.5)	32.4 (58.5)	8.6 (15.5)	7.5 (13.5)	n/a	55.4
1909	12.9 (12.2)	39.8 (37.5)	40.5 (38.2)	12.8 (12.1)	n/a	106.0
1914	34.8 (19.1)	46.2 (25.4)	88.8 (48.8)	12.3 (6.8)	n/a	182.1
1920	116.3 (26.3)	55.2 (12.5)	211.0 (47.6)	24.9 (5.6)	35.5 (8.0)	442.9
1925	259.6 (34.3)	59.7 (7.9)	365.0 (48.2)	31.1 (4.1)	42.2 (5.6)	757.6
1930	432.2 (44.8)	49.2 (5.1)	372.5 (38.6)	34.2 (3.5)	76.9 (8.0)	965.0

Expanded Coal Consumption

The most important factor in the mid-Atlantic's transition into a mineral economy between 1860 and 1900 came from coal, not petroleum. As shown in chapters 1 and 2, the development of an extensive trade in anthracite coal initiated a move away from the organic economy. By 1860, with total anthracite production at just over ten million tons (and a little more than eight million transported to eastern markets), the mid-Atlantic had already begun to develop a mineral economy. Over the next forty years, coal consumption continued to grow at a rapid pace. By 1900, anthracite production had increased more than five-fold to over 57 million tons (Table 4.11). Moreover, this period witnessed a dramatic expansion of the utilization of Pennsylvania's bituminous coalfields. While less than five million tons were mined in 1860, production practically doubled every decade until there were nearly 80 million tons produced in 1900.

⁸⁸ Note: % of total is indicated in parentheses. Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 93.

To put this growth of into perspective, Pennsylvania's coal production in 1900 provided a thermal energy equivalent roughly 10 times greater than American petroleum production in the same year.⁸⁹ Another measure of the significance of this growth was that Pennsylvania coal mining in 1900 generated the heat equivalent of a forest nearly four times the size of the state.⁹⁰ Therefore, while petroleum garnered large amounts of attention as a new energy source, the expanded use of coal during this period represented the most significant increase in the mid-Atlantic's dependence on fossil fuel energy.

Table 4.11: Pennsylvania Coal Production, in Tons, 1860-1900⁹¹

Year	Anthracite	Rate of increase	Bituminous	Rate of increase
1860	10,983,972		4,710,400	
1870	19,958,064	82%	9,223,856	96%
1880	28,649,812	44%	21,280,000	131%
1890	46,481,641	62%	42,302,173	99%
1900	57,367,915	23%	79,842,326	89%

Conclusions

Regional Differentiation

Oil altered life in the mid-Atlantic, but in different ways in different places. In many ways, the regional patterns of oil were similar to the dynamics of the coal industry.

Petroleum was produced in rural locations but refined and consumed mainly in urban

⁸⁹ 57,367,915 tons of anthracite would provide the thermal equivalent of 1,447,892,600 million BTUs while 79,842,326 tons of bituminous would generate 2,091,860,400 million BTUs for a total of 3,539,753,000 million BTUs. 63,620,529 barrels of oil provided the thermal equivalent of 363,096,550 million BTUs.

⁹⁰ 3,539,753,000 million BTUs were equivalent to 169,317,564 cords of wood (average BTU of 20,960,000 per cord). The sustainable yield of one cord of wood requires 2/3 of an acre (see chapter 2) therefore necessitating 112,878,376 acres, or 176,372 square miles (there are 640 acres in a square mile). As Pennsylvania's area is 46,055 square miles, coal provided the heat equivalent of a forest nearly four times the state's total area.

⁹¹ 1860, 1870, and 1880 data from Howard Nicholas Eavenson, *The First Century and a Quarter of American Coal Industry* (Pittsburgh, Pa.: Privately printed by the Baltimore Weekly Press, 1942), 431. 1890 data from United States Geological Survey, *Mineral Resources of the United States, 1891* (Washington: Government Printing Office, 1893), 178. 1900 data from United States Geological Survey, *Mineral Resources of the United States, 1901*, 292, 295.

locations. The worst environmental harm occurred in the Oil Regions and the producers of oil reaped only a small share of the profits. One pattern was noticeably different between coal and oil: the transport of oil via pipeline eliminated the possibility for reciprocal trade to develop along the energy pathways.

As with coal, urban residents benefited the most from the development of the oil trade. City dwellers used the most oil in the greatest number of ways. Kerosene and naphtha oils offered cheap and bright illumination. Lubricants and fuel oils increased the efficiency of urban industries. Moreover, the location of refineries in urban locations created jobs and wealth in cities such as Cleveland, New York, and Philadelphia.

Oil producers and residents living in the Oil Regions experienced many fewer benefits and more of the costs. Kerosene and lubricants may have made life easier, but the total amounts consumed were minor in comparison with cities. Moreover, the financial benefits were much less significant. Although many landowners and oil producers earned small fortunes, the bulk of the industry's profits went to refiners, marketers, and Standard Oil executives in Philadelphia, Cleveland, and New York. Adjusted to present-day values, while some oil producers became millionaires, the billionaires lived in distant cities.

Those living in the Oil Regions also experienced the worst environmental harms. Oil drilling was a highly destructive process. Forests were clear-cut to provide timber for derricks. Poor storage facilities meant that large amounts of oil spilled onto the ground and ended up in streams and rivers. In the race to maximize production, large amounts of

oil were wasted.⁹² These observations were clear to contemporaries as well as

historians. Stephen Peckham described the scene this way:

“The development of the oil territory proceeds, after its existence has been demonstrated, without regard to any other interest. The derrick comes like an army of occupation. In the towns a door-yard or a garden alike surrender its claims. The farms, fields, orchards, or gardens alike are lost to agriculture and given to oil, and on the forest-covered hills the most beautiful and valuable timber is ruthlessly cut and left to rot in huge heaps wherever a road or a derrick demands room. Pipe-lines are run over the hills and through the valleys, through door-yards, along streets, across streets and railroads, and here and there the vast storage-tanks stand, a perpetual menace to everything near them that will burn. Nothing that I ever beheld reminded me so forcibly of the dire destruction of war as the scenes I beheld in and around Bradford at the close of the census year; and nothing else but the necessities of an army commands such a complete sacrifice of every other interest or leaves such a scene of ruin and desolation.”⁹³

Just as the Anthracite Regions in northeast Pennsylvania were left to deal with the bulk of the environmental harms of mining, the Oil Regions bore the brunt of the damages from oil production.

Cities had a more mixed experience of the environmental effects of oil consumption. Kerosene was an improvement over burning candles in terms of indoor air quality. Naphtha and fuel oils gave off some emissions, but far less than the amounts of coal already being burnt in cities. However, refining produced extensive pollution. In addition to smoke from coal fires, large amounts of chemicals were dumped into rivers and oil leaked out of pipes and tanks. As Jonathan Wlasiuk has shown, Standard Oil’s Cleveland refineries caused significant environmental damage to the Cuyahoga River, forcing the city to seek new sources of drinking water.⁹⁴

⁹² For the best account of the environmental degradation of the early oil regions, see Black, *Petrolia: The Landscape of America's First Oil Boom*.

⁹³ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 76.

⁹⁴ Wlasiuk, Jonathan, “Refining Nature: Standard Oil’s Cuyahoga in the Gilded Age” (paper presented at annual meeting of the American Society for Environmental History, Tallahassee, FL, February 27th, 2009).

For those living along the paths of oil pipelines, oil was a mixed blessing.

Most farmers were given generous stipends in exchange for granting rights-of-way for a pipeline across their property. On the other hand, oil pipelines leaked regularly and occasionally burst. Although we have little data on how much oil leaked out of pipes, we know that it happened regularly.⁹⁵ Farmers traded cash for the risk of their land being ruined by oil leaks.

In addition, those living along the paths of pipelines did not benefit from the reciprocal trade relations initiated by the anthracite canals. By providing two-way transport of a wide range of goods, anthracite canals supported the development of an anthracite iron industry between the Anthracite Regions and the large cities at the termini of the pathways. Pipelines, which shipped only one good in one direction, did not lead to the development of subsidiary industries along their path. Therefore, the areas along the paths of the pipelines did not benefit nearly as much as the regions along the banks of the anthracite canals.

The distribution of kerosene throughout the rural regions of the mid-Atlantic likely had a slightly beneficial, although not substantial, effect on those living on farms. With access to a cheap and effective illuminant, people had access to better lighting options. If they desired, they could use this light to alleviate the darkness of the winter evenings, read more, or perform detailed handiwork at night. Petroleum lubricants may have made work on the farm easier by reducing friction. However, because the levels of

⁹⁵ It was a regular practice for Tide-Water engineers to fix leaking pipes: Buente, *Autobiography of an Oil Company*, 28. In addition, Ida Tarbell includes a picture of a burst pipe spewing oil as part of her account of the oil industry: Tarbell, *The History of the Standard Oil Company*, II, 76. The Derrick's Handbook of Petroleum reported at least five major pipe breaks between 1885 and 1887: *The Derrick's Hand-Book of Petroleum; a Complete Chronological and Statistical Review of Petroleum Developments from 1859 to 1899*, I, 385, 399, 417, 431, 454.

consumption were relatively minor, oil did not lead to a restructuring of rural life in the mid-Atlantic before the introduction of automobiles in the twentieth century.⁹⁶

Creating Dependence

By 1900, many mid-Atlantic residents had come to use petroleum extensively in their lives. Boosters were quick to note its general usefulness and to declare that it had become a practical necessity. As Stephen Peckham claimed in his 1885 report on the industry, “petroleum has become one of the indispensable needs of civilized man, and ministers to his wants in such a multitude of forms and under such a multitude of circumstances that it may be safely said that it ameliorates the conditions of his struggle with external nature, adds comfort to health, and soothes in sickness, prolonging his active life by extending the day into the domain of night over all that portion of the earth’s surface accessible to commerce.”⁹⁷ Yet once people began using petroleum, it initiated behaviors that could only be reversed with great difficulty. Kerosene helped accustom individuals to the benefits of artificial lighting, thereby encouraging its expanded use. Even though electricity overtook kerosene as the main illuminant for mid-Atlantic residents in the twentieth century, oil played a role in changing people’s expectations for how homes and factories should be lit. Once new lubricants were introduced, they made it possible for machinery and vehicles to operate at higher levels of heat and friction. As the capacities of industrial technologies were expanded, it

⁹⁶Gasoline-powered automobiles and light trucks made a greater impact on daily life on farms than any other form of fossil fuel consumption because they could assist in transportation (much of the labor on farms) and provide a source of fixed power to operate machinery like saw belts or washing machines. Michael Berger, *The Devil Wagon in God's Country: The Automobile and Social Change in Rural America, 1893-1929* (Hamden, CT: Archon Books, 1979).

⁹⁷ Peckham, *Report on the Production, Technology, and Uses of Petroleum and Its Products*, 262.

created an ongoing need for more and better petroleum lubricants. Fuel oil enabled the expansion of transport networks in areas without other fossil fuel endowments, such as California. Once these railroads were built, they required a constant source of petroleum to keep them moving. Without the continued supply of oil, several aspects of home and work life would no longer have been possible.

Moreover, as automobiles became a common form of personal transport in the first decades of the twentieth century, Americans quickly became dependent on cheap and abundant petroleum in order to drive cars to and from home, work, and vacation sites. The transport of goods also began a switch from railroads to long-distance trucks and short-distance delivery vans. The oil infrastructure created during the nineteenth century—pipelines, drilling technologies, refining techniques, marketing stations—played a critical role in expanding the consumption of oil in the twentieth century and creating a world in which that supply was necessary to society's smooth functioning.

A Region Transformed

The transport and consumption of petroleum in the mid-Atlantic contributed to several broad social changes in the region and nation between 1860 and 1900. The deepening of the mineral economy expanded the depth and breadth of industrial activity in the mid-Atlantic. In addition, the boundaries of the nation's industrial district expanded westwards across southern New York and Pennsylvania to include parts of the mid-West including Ohio and Chicago. The creation of large corporations like the Standard Oil Trust, U.S. Steel, and the railroads generated new social and political questions about how to protect citizens and workers against these powerful organizations.

Finally, many workers pursued unionization efforts in response to shifting work conditions and the growing power of corporations.

The early stages of industrialization in the mid-Atlantic during the antebellum era set the stage for the dramatic expansion of industrial enterprises in the latter half of the nineteenth century. In 1860, the United States trailed Great Britain, France, and Germany in industrial output. By 1900, American workers produced more goods than all three European nations combined. A quarter of the nation's labor force—5.9 million people—worked in factories. Fossil fuel energy—coal to provide heat and power, petroleum for lighting, fuel, and lubrication—helped industrial operations increase their output five-fold during the period.⁹⁸

The phenomenal growth of industrial output did not occur steadily, nor did it benefit all people and places equally. Devastating depressions from 1873-78 and 1893-97 forced many business owners to shut their doors and lay off thousands of workers. Some cities grew disproportionately—New York and Philadelphia remained the nation's main manufacturing centers while Pittsburgh, Cleveland, Buffalo, and Chicago grew dramatically—and others were overshadowed—Lowell was surpassed by other textile centers while Troy, New York and Patterson, New Jersey experienced relative declines. Urban locations attracted the lion's share of new manufacturing centers. The largest ten cities increased their total share of manufacturing from 24 percent of the nation's output to 38 percent between 1860 and 1900. Moreover, the rich got richer: the top 1 percent

⁹⁸ Licht, *Industrializing America: The Nineteenth Century*, 102.

owned 52 percent of the nation's wealth while the bottom 44 percent only owned 1.2 percent in 1890.⁹⁹

The geography of industrialization changed as well. While the eastern mid-Atlantic and mill towns of New England were the nation's primary manufacturing centers in the antebellum era, industrial growth spread westward over the latter half of the nineteenth century. The result was a broad industrial heartland bordered by Baltimore, Philadelphia, and New York on the east, Pittsburgh and Cincinnati on the south, Albany, Rochester, Buffalo, and Cleveland on the north, and Chicago on the west.¹⁰⁰ This industrial heartland contained the great bulk of the nation's industrial capacity.

The transport and consumption of oil shaped and reflected these patterns. The Oil Regions were similar to Troy and Lowell as promising refining sites that got passed over in favor of Cleveland, New York, and Philadelphia. John D. Rockefeller's ability to control the oil industry contributed to the concentration of wealth in the hands of a few. Finally, transport infrastructure played a crucial role in creating the boundaries of the industrial heartland. Most notably, the outlines of the industrial heartland appear clearly in three of the maps already shown in this chapter. The location of American manufacturing shows a remarkable overlap with the railroad system circa 1875, the pipeline system in 1900, and the distribution of Standard Oil marketing stations in 1906. Railroads and pipelines brought cheap and abundant coal and oil to the cities along their paths, thereby giving them an advantage over other locations. Transport infrastructure

⁹⁹ Statistics from *Ibid.*, 125, 181, 183.

¹⁰⁰ On the creation of this industrial corridor, see: Meinig, *The Shaping of America: A Geographical Perspective on 500 Years of History*, Volume II: 374-99; Allan Pred, *The Spatial Dynamics of U.S. Urban-Industrial Growth, 1800-1914; Interpretive and Theoretical Essays* (Cambridge, Mass.: M.I.T. Press, 1966).

both reflected and shaped this geography. As geographers have noted about this heartland: “The really striking feature is the absence of any major industrial center ... south of the B&O Railroad.”¹⁰¹

The spread of an industrial heartland to the west did not mean the eclipse or decline of the mid-Atlantic. Pennsylvania, New York, and New Jersey remained leading industrial states while New York, Philadelphia, Pittsburgh, and Baltimore were among the nation’s preeminent industrial cities. Instead, the spread of industry to Ohio and Illinois reflected the extension of the mid-Atlantic’s style of fossil-fuel powered industrialization to other parts of the nation. Cities like Cleveland and Chicago were similar to Philadelphia and New York in that they had limited supplies of water-power. Their industrial expansion depended on coal and oil.

Corporations grew in tandem with the nation’s industrial growth. While corporations had already been seen as a threat to republican values in the antebellum era, their growth in number and scale created a range of new social challenges in the latter half of the nineteenth century.¹⁰² Some of these problems were internal. How could a company operate successfully when it had to handle multiple divisions, a diverse product line, and hundreds or thousands of laborers? One response was the rise of bureaucratic management. Hundreds of unnamed middle managers innovated with new management forms and created procedures and practices to handle the complexities of corporations.¹⁰³

¹⁰¹ Meinig, *The Shaping of America: A Geographical Perspective on 500 Years of History*, Volume II: 388.

¹⁰² For a critical take on the rise of corporations, see: William Roy, *Socializing Capital: The Rise of the Large Industrial Corporation in America* (Princeton, N.J.: Princeton University Press, 1997); Charles Perrow, *Organizing America: Wealth, Power, and the Origins of Corporate Capitalism* (Princeton, N.J.: Princeton University Press, 2002).

¹⁰³ Chandler, *The Visible Hand: The Managerial Revolution in American Business*; Olivier Zunz, *Making America Corporate, 1870-1920* (Chicago: University of Chicago Press, 1990).

In addition, they pioneered new forms of information flows to keep the company's operations in order.¹⁰⁴

Corporations posed a series of problems for those outside the boardroom walls as well. Small manufacturing firms had to adjust their strategies to avoid being swallowed by large conglomerates. Many managed to do so, largely by specializing in high-quality batch production.¹⁰⁵ The disproportionate power of corporations over workers led many laborers to join unions. Farmers, who often felt victimized by the seemingly arbitrary practices of railroad companies, organized themselves under the auspices of the Grange to fight back.¹⁰⁶ Muckraking journalists like Upton Sinclair and Ida Tarbell protested the unchecked power of corporations. Finally, some politicians sought to expand the role of the state to provide a check against corporate abuses. These efforts led to the creation of the Interstate Commerce and Sherman Antitrust Acts and the rise of government regulation.

The oil industry offered one of the most visible examples of the dangers of corporations. The monopoly powers of John D. Rockefeller's Standard Oil Trust were widely denounced in hearings before state commissions, articles by Ida Tarbell and Henry Demarest Lloyd, and the protests of oilmen. The various hearings, legal actions, and ultimate dissolving of the Standard Oil Trust figured prominently in the development of a political response to corporate power in America.

Finally, workers experienced numerous changes during this period. First, the demographics of labor shifted. Those employed in industrial occupations grew from 1.5

¹⁰⁴ JoAnne Yates, *Control through Communication: The Rise of System in American Management* (Baltimore: Johns Hopkins University Press, 1989).

¹⁰⁵ Scranton, *Endless Novelty: Specialty Production and American Industrialization, 1865-1925*.

¹⁰⁶ Licht, *Industrializing America: The Nineteenth Century*, 186-88.

million in 1860 to 5.9 million in 1900. Their backgrounds changed as well: more than 80 percent were born in foreign countries or were the children of immigrants.¹⁰⁷ Second, laborers found themselves dealing with corporations instead of shop owners. This meant that laborers were removed from the owners of the enterprises, managed by foremen (many of whom were notorious for showing favoritism and demanding bribes for good jobs), and had considerably less power over the workplace environment. In response, many laborers decided to form unions and protest their diminished status. They created the National Labor Union in 1866, the Knights of Labor in 1869, the American Federation of Labor in 1886, and many other unions. Fossil fuel energy contributed to these changes by helping give rise to large corporations and the expansion of industrial enterprise. Therefore, coal and oil were linked to the organization of labor unions, which, in turn, would have significant consequences for the nation's political economy in the twentieth century.

Coal and oil remade the society and economy of the mid-Atlantic during the nineteenth century by providing new ways to heat and light homes, power machinery, and transport goods and people around the nation. In the last quarter of the century, inventors and entrepreneurs began to generate and harness a new medium that would further revolutionize the mid-Atlantic's energy base: electricity. The channeling of electricity through wires offered a flexible form of energy delivery that would extend the development of the mineral economy in the region. It is to this story that we now turn.

¹⁰⁷ Ibid., 102, 127.

Chapter 5: River of Power: The Holtwood Dam and the Development of a Mid-Atlantic Power Grid, 1900-1930

Electricity captivated Americans in the late nineteenth century. Its unique combination of invisibility, danger, and wide range of uses drew reactions ranging from awe and wonder to terror. For many, it was magical: “Electricity was the sign of Edison’s genius, the wonder of the age, the hallmark of progress. It was a mysterious power Americans had long connected to magnetism, the nervous system, heat, power, lightning, sex, health, and light.”¹ As electrification spread across the mid-Atlantic during the early part of the twentieth century, it would change more than people’s mental states: it would build on and expand the social, economic, and environmental transformations initiated by coal and oil.

As a source of light and power, electricity had profound impacts for mid-Atlantic residents. It led to new patterns of suburban living, changes in labor arrangements, and the widespread use of fossil fuel-based mechanical energy in the home. For those with access to cheap and reliable electricity, it made many aspects of life easier. Better lighting helped maintain eyesight and encouraged reading. Streetcars allowed working families to purchase houses in the newly developing suburbs. Electric machines were often more reliable, quiet, and safe than those driven by steam. Moreover, electricity gave rise to a host of leisure activities including the widespread dissemination of radios and movies. There were downsides as well. Well-lit factories made graveyard shifts practical. Suburbs often exacerbated class and ethnic segregation. Moreover, not everyone had the same access to electricity or paid the same rates. Electrification was

¹ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 1.

largely an urban phenomenon. Residential consumers, when they had access to electricity, usually paid rates three to four times higher than industrial consumers.

By transforming the lives of mid-Atlantic residents, electricity had much in common with coal and oil. Most importantly, turning the potential of fossil fuels or falling water into energy that consumers would use (and pay for) required major alterations of the built environment.² While dams, generating stations, and dynamos were necessary for producing electricity, it was the creation of vast networks of transmission wires that allowed this power to travel to the places where consumers were located. In doing so, transmission wires created new energy landscapes that made electricity cheap, abundant, and reliable in certain places.

This chapter studies the development of transmission wires in the mid-Atlantic between 1900 and 1930. The first half of the chapter analyzes the transmission wires extending from the Holtwood hydroelectric dam on the Susquehanna River. The Holtwood dam was one of the pioneering electrical projects in the mid-Atlantic during this period and its construction highlights the challenges, choices, and contingencies shaping the development of transmission wires. The second half of the chapter examines the emergence of a broader electrical grid throughout the region. I conclude with an exploration of the political debates over how integration should be managed and who should own the network. These debates make it clear that there were several possible

² Even though hydro-electricity, and the Holtwood Dam, was not powered by fossil fuels, it was more characteristic of the mineral economy than the organic. Hydroelectric dams were usually large-scale installations that shipped large amounts of power over long distances. They operated in networks that used coal-driven electricity generating plants to supplement the flow of rivers. Therefore, given the ways these plants were built and operated in the mid-Atlantic during the first years of the twentieth century, it makes sense to study them as part of the mineral economy.

forms the electric grid could take and that choices about how to build and operate transmission wires shaped the social consequences of electricity in the mid-Atlantic.

Taming the Susquehanna River: The Holtwood Dam

The Susquehanna River has figured prominently in the history of the mid-Atlantic. For hundreds of years, Native American groups lived along its banks and fished its waters. Captain John Smith led the first survey of the river by European settlers in 1608 and William Penn envisioned a sister city for Philadelphia that would be located where the Susquehanna and Conestoga rivers met.³ As discussed in Chapter 1, questions over whether the lucrative agricultural trade of central Pennsylvania would flow south along the Susquehanna to Baltimore or east along roads to Philadelphia focused the attention of each city's merchants on the navigability of the Susquehanna. The perceived threat of the Susquehanna to Philadelphia's trade prospects encouraged boosters to develop the Pennsylvania canal network in the nineteenth century. At the dawn of the twentieth century, the Susquehanna River would once again take a prominent role in mid-Atlantic affairs as the site of major hydroelectric developments.

While the Susquehanna River was one of the largest waterways in the region, its natural features had frustrated many in the mid-Atlantic. Whereas most of the other major rivers along the eastern seaboard had been supporting significant amounts of transport and/or power for several decades, the lower Susquehanna was relatively

³ "A Short Story of the History of the Susquehanna River in Lancaster County" August 3, 1943. Pennsylvania Power & Light Collection, Pennsylvania Water & Power Company Files, Accession 1552, Box 149, Folder 3. Hagley Museum and Library, Wilmington, DE. Hereafter, this collection will be referred to as "Hagley PWP Collection."

undeveloped by the end of the nineteenth century. Two distinct features of the river limited its effectiveness for either purpose. First, over the course of a year there could be great fluctuations in water level between the raging torrents common during the spring thaws and the slow trickle typical of late summer, thereby hampering navigation. These variable water levels also frustrated power developments because it was difficult to site a mill along the river's banks. The full strength of a spring flood would provide too much power to control effectively, while lower water levels might not even reach a water wheel.

Second, the river's greatest drops in elevation occurred over the last forty miles. Most major rivers have large drops near their sources and flatten out as they travel to the sea, thereby making it easy to transport goods from inland to the coast and vice versa. Boats traveling down the Susquehanna, on the other hand, found that the most difficult part of their journey was reaching these broader markets because of the steep and dangerous final descent. This also meant that goods could not be shipped efficiently up the Susquehanna from the Chesapeake Bay. In addition, the concentration of falls near the end of the river inhibited power developments because most nineteenth century mills were not capable of harnessing such large sources of power.⁴ It was not until the 1870s that a development of paper mills at York Haven sought to use the lower Susquehanna

⁴ The developments at Lowell along the Merrimack are an exception that proves the rule. The only way that such a major water power site could be developed was with the investment of significant sums of capital.

for industrial power.⁵ As a result of these features, the Susquehanna River was not nearly as developed as most other major rivers along the eastern seaboard around 1900.⁶

The development of the electric industry and the push towards hydroelectricity changed the course of the Susquehanna River and its role in the mid-Atlantic. The first hydroelectric plant was established in Wisconsin in 1882 and in the 1890s, the development of extensive power plants at Niagara Falls proved the viability of obtaining large amounts of electricity from falling water. As hydroelectric technologies such as dams, turbines, and transmission wires improved, people began to turn their attention to other opportunities, including the Susquehanna River.

The first hydroelectric facilities on the Susquehanna were built along its tributaries, including the Rock Hill and Wabank plants on Conestoga Creek (1896-7) the Colemanville plant on Pequea Creek (1896) and the Delta Electric Power Co. plant on Muddy Creek (1896).⁷ At York Haven, a group created a hydroelectric facility on the Susquehanna River by erecting a wing-dam part of the way across the river.⁸ In many ways, the development of these small plants fit the pattern of the organic economy, where falling water was used to generate power for a local mill.

Several parties had more ambitious aims. They knew that a dam erected across the entire breadth of the river would create a power potential of more than 75,000 kw,

⁵ R. L. Thomas, "The Development of a Regional Power System" June 6, 1935, Hagley PWP Collection, Acc 1552, Box 149, Folder 14.

⁶ Nature did provide one important advantage to those looking to develop the river: the banks of the lower Susquehanna featured steep cliffs that were relatively unpopulated. This meant that if the river were dammed, the cliffs would reduce the amount of flooded land, thereby making it much cheaper for a company to obtain the necessary property rights.

⁷ These plants generally had a capacity of 500 – 1,000 kw. R. L. Thomas, "The Development of a Regional Power System" June 6, 1935, Hagley PWP Collection, Acc 1552, Box 149, Folder 14, p. 3.

⁸ The York Haven plant was built by a group of men including George Burbank who had been active in the creation of the Niagara Falls project. This facility had an initial capacity of 5,000 kw that was later expanded to 15,000 kw. Ibid., p. 4.

dwarfing the output of other facilities on the Susquehanna. Such a facility would no longer be characteristic of the organic economy. Given the rural nature of the surrounding areas, there were no local markets for such a large supply of electricity. Instead, prospective dam builders could only obtain financing if the power were to be sent to distant urban markets. Instead of people moving to a site of energy abundance, the dam and its wires would ship the energy elsewhere. Such a dam would be a hybrid between the organic (capturing renewable flows of solar energy) and mineral economies (producing concentrated power and transporting it to distant markets).

The McCall Ferry Power Company

The McCall Ferry Power Company led the first effort to transform the Susquehanna River into a source of energy for distant markets. The scale of the project was immense. The dam would need to stretch over half a mile making it the longest in the United States and comparable to the recently built Aswan Dam in Egypt.⁹ The hydroelectric output of the powerhouse would only be exceeded by Niagara Falls on all rivers east of the Mississippi. To tackle such an immense project, the McCall Ferry Power Company was created in 1905 with the financial support of New York capitalists and an elite group of engineers with extensive experience working on the Panama Canal.¹⁰

⁹ See several of the articles in Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 13.

¹⁰ The financing for the project came mostly from New York bankers including the Bertron, Storrs and Griscom banking firm and Harvey Fiske and Sons of New York. In addition to a number of prominent capitalists on the board of directors, the firm also hired several well-known engineers to supervise the work, including George S. Morrison (who died during construction), Cary T. Hutchinson, Boyd Ehle (who worked with Morrison on the Panama Canal), F. Q. Blackwell, and Charles Main.

Work to survey the river and secure land rights had actually begun several years before the company was officially incorporated. Engineers including Boyd Ehle and Robert Anderson led surveys of the river in 1901.¹¹ By 1902, Cary T. Hutchinson, one of the company's directors, had purchased many land rights in the area of McCall's Ferry, an inn along the edge of the river along with a ferry service for those wishing to cross the river.¹² Much of this work was done in secret, largely because other parties were seeking to procure land rights to develop the river themselves.¹³

The McCall's Ferry site had several advantages for a hydroelectric dam: there was a large island in the middle of the river that would make dam construction easier, a natural tailrace for the power house's water discharge between the island and east side of the river, and a bend in the river above the site that meant the large blocks of ice that swept down the river would flow to the west side of the river and away from the power house, thereby preventing damage. However, there were disadvantages. Most notably, it was a very rural and remote site. The only local structure of note was a small inn forcing the company to import laborers, erect housing, build construction plants, and supply any other facilities it needed.

¹¹ Affidavit of Robert Anderson, September 30, 1926, p. 1. Hagley PWP Collection, Accession 1962, Box 215, Folder 13.

¹² When the McCall Ferry Power Company went into receivership, it had to list all its assets in court papers. This included over 100 properties which detail who purchased the property and when. Recurrent names in these deeds are Frederick Shoff, Cary T. Hutchinson, and James Harlow. George Willson and William Beyer, who were likely agents of Cary T. Hutchinson, also purchased many of the properties. The full list of properties are listed in: "Amended Bill of Complaint, Answer, Decree Appointing Receiver and Certificate of Clerk of Court as to Entry of Bond of Receiver" Circuit Court of the United States (Eastern District of Pennsylvania), April Sessions, 1909. No. 329, p. 26. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

¹³ For example, James Harlow and the Susquehanna Electric Power Company purchased properties in the same area as did the agents of the Susquehanna Power Company, an organization with connections to New York financiers.

By 1905, Hutchinson and his fellow directors felt sufficiently confident in their surveys and property rights to create the McCall Ferry Power Company and begin raising the several millions of dollars needed to dam the river. Enough capital was raised by October of 1906 to begin construction. The company brought in several hundred immigrant laborers to perform the necessary work, housing them in simple shacks near the construction site.¹⁴ The skilled “American” workers were put up in houses offering room and board services.¹⁵ The work was managed by Hugh L. Cooper, who went on to a significant career directing infrastructure developments across the globe.¹⁶

The incredible labor and financial resources necessary to construct a dam were not the only challenges the company faced. As word was spread to local communities about the building of the dam, it caused a great stir, particularly among shad fishermen. Because the dam was being built in such a rural location and the company had kept quiet during its surveying, corporate organizing, and property purchases, few people had a clear idea of what a large undertaking the project would be or could imagine a dam stretching over half a mile restraining the turbid waters of the Susquehanna. When newspaper reports began circulating in the spring of 1906, however, many local residents began to protest the proposed dam. In particular, shad fishermen feared the dam would

¹⁴ Similar to the construction of canals in the early nineteenth century, most of the hard work was performed by those in a low social position. Moreover, the opinions of the directors reflected ethnic stereotypes. According to Christie Hutchinson, brother of Cary and a lawyer for the company, “most of the force now is Italian, our superintendents finding that, on the whole, Italians are better workers than Slavs.” “York to Have Power from McCall’s Ferry” July 6, 1906. An article in a York newspaper in Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 13. “Developing Electricity from the Susquehanna River” *Manufacturers’ Record*, October 4, 1906.

¹⁵ Immigrant laborers were typically paid \$1.50 per day and paid \$1.00 per month for the shacks they lived in. Skilled workmen were paid \$2.50-\$3.25 per day and \$4.50-\$6.00 per week for room and board. “York to Have Power from McCall’s Ferry” July 6, 1906. An article in a York newspaper in Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 13.

¹⁶ Harold Dorn, “Hugh Lincoln Cooper and the First Detente,” *Technology and Culture* 20, no. 2 (1979).

end their livelihoods because the fish was a migratory species that would be cut off from its breeding grounds.¹⁷ Others objected to the raising of the river behind the dam, which would submerge favorite local islands, such as the Indian Steps. These rock islands in the river were attractive fishing spots and local lore held that William Penn had bequeathed them to local residents.¹⁸

These protests were powerful enough to draw the attention of Pennsylvania's Fish Warden, W. E. Meehan, who brought the issues to Pennsylvania's Attorney-General Hampton L. Carson. Carson questioned whether the company had a right to build a dam across the entire breadth of the river since it would interfere with the migration of fish and the movement of vessels. In particular, Carson was not convinced that the Mill Act of 1806, by which the company claimed the right to build its dam, was applicable. In August 1906, Carson appealed to the District Court of Pennsylvania in Dauphin County for a preliminary injunction halting work on the dam.¹⁹ On January 14, 1907, a compromise agreement was reached where the company was allowed to proceed with work on the dam on the conditions that it provide a fishway for the shad and facilitate navigation if any party built a canal above the dam.²⁰ This decision ended Carson's efforts to halt the dam and effectively ceased any protest by the shad fishermen that would threaten the project.

The McCall Ferry Power Company also had to secure additional land rights. The geography of the Susquehanna River made this task much easier. Along its lower

¹⁷ "Alderman Aughenbaugh Insists that Power Company Dam Will Destroy Fish" *York Gazette*, April 2, 1906; "Don't Give Up the River" *York Dispatch* March 27, 1906.

¹⁸ "The Great River Work" *Lancaster New Era* March 13, 1906.

¹⁹ "M'Call's Ferry Is In Danger" *Wilmington Evening Journal*, August 15, 1906.

²⁰ A copy of the relevant part of the court's decision is at: Hagley PWP Collection, Accession 1962, Box 35, Folder: "McCall Ferry Power Company – Decree of Court of Common Pleas – Dauphin County Dated January 14, 1907".

lengths, steep cliffs border most of the river's banks. These cliffs were largely uninhabited, making the land rights cheaper to purchase. Moreover, they contained the lake that would be created behind the dam to a relatively small area, lowering the overall amount of property that the company needed to obtain.

Despite this favorable geography, there were significant challenges to obtaining the necessary property rights. First, the company had to negotiate agreements with the other parties who had purchased rights in the hope of constructing their own dam.²¹ Second, they had to acquire additional properties from landowners. Despite a reputation for fair dealing—an editorial on the development of the dam acknowledged that the company had been upfront with landholders, often paying double the cost “had it resorted to chicanery and deception”—the company was not able to obtain all the land it desired.²² For example, a local resident owned land that would be flooded if the dam was raised at its originally designed height of 85 feet. Because the company could not obtain his property and a few other sites as well, they begrudgingly lowered the height of the dam to 65 feet. This involved a significant loss of power, but made the project more feasible in the short term.²³

²¹ The McCall Ferry Power Company was able to purchase the property rights of the Susquehanna Electric Power Company. However, it had more difficulty acquiring the rights of the Susquehanna Power Company. Eventually, the two parties divided their land holdings, giving the McCall Ferry Power Company the rights to lands at McCall's Ferry and the Susquehanna Power Company the rights to lands near Conowingo, MD. The agreement also forced the McCall Ferry Power Company to invest in the stock of the Susquehanna Power Company. “Making a Great River Work for Men,” *Baltimore Sun*, February 20, 1910. The agreement between the McCall Ferry Power Company and Susquehanna Power Company is dated August 11, 1908. Reprinted in “Amended Bill of Complaint, Answer, Decree Appointing Receiver and Certificate of Clerk of Court as to Entry of Bond of Receiver” Circuit Court of the United States (Eastern District of Pennsylvania), April Sessions, 1909. No. 329, Appendix D. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

²² “Don't Give Up the River” *York Dispatch* March 27, 1906.

²³ “The Land Damage Cases” October 19, 1906. Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 19. In 1935, R. L. Thomas of PWP noted that in the long term, the decision to lower the dam left a sufficient fall above McCall's Ferry to warrant the building of the Safe Harbor plant:

Finally, the company had to make arrangements with the Pennsylvania Railroad Company, as the dam would flood the tracks of the Columbia & Port Deposit Railroad running along the Susquehanna River. The company needed to relay tracks for the railroad for six miles above and below the dam, a significant expense.²⁴ When a few landholders refused to sell their properties at prices considered fair by the McCall Ferry executives, the directors turned to the strength of the Pennsylvania Railroad Company, still one of the state's most powerful corporations, to resolve the issue. Because the Pennsylvania Railroad had eminent domain privileges, the two companies worked out an arrangement whereby the railroad company used these rights to purchase the land at a cheaper price. While several landowners sued the two companies on grounds that the railroad did not have the right to use its eminent domain privileges for the benefit of the dam company, the courts rejected the landowners' claims.²⁵

While the McCall Ferry Power Company successfully navigated the acquisition of land rights, thwarted legal obstacles to the dam, and made significant headway on constructing the dam, it met its demise with the collapse of the financial markets in the fall of 1907. Even though the company had completed 80 percent of the work on the dam, it found itself unable to raise additional funds to complete the project. By March of 1908, work had ceased entirely. According to one of the company's engineers, the dam was complete with the exception of fifteen 40-foot sections letting the water through and

R. L. Thomas, "The Development of a Regional Power System" June 6, 1935, Hagley PWP Collection, Acc 1552, Box 149, Folder 14, p. 7.

²⁴ They needed to raise the tracks below the dam as well to provide a gentle incline to the higher tracks above the dam.

²⁵ "The Land Damage Cases" October 19, 1906, Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 19; "Railroad Work Stopped" *Lancaster Intelligencer*, Oct. 12, 1906.

the company hoped to acquire new funds.²⁶ By December 15, 1908, the company could no longer meet the interest payments on its bonds and was forced into receivership.²⁷ As a result, the first attempt to install a major hydroelectric development on the Susquehanna River came to a close.²⁸

Aldred Takes Over – the Pennsylvania Water & Power Company

The failure of the McCall Ferry Power Company revealed that a combination of prominent New York financiers and engineers was not sufficient to transform the potential water power of the Susquehanna River into a usable and profitable commodity. However, by constructing 80 percent of the dam before running out of money, the company's efforts made it likely that a new party would complete the project. Once the

²⁶ "'White Coal' From the Susquehanna" *Lancaster New Era*?, March 4, 1908 in Hagley PWP Collection, Accession 1962, *McCall Ferry Power Co Scrap Book*, p. 33.

²⁷ Letter from Bondholders Committee to Holders of First Mortgage Bonds and Preferred Stock of McCall Ferry Power Company, December 7, 1908. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

²⁸ Several factors contributed to the financial failure of the McCall Ferry Power Company. The most immediate explanation was the Panic of 1907. When the Knickerbocker Trust Company failed in its effort to corner the copper market, it led to a cascading series of bank failures. Investors who had been burned either had no additional capital to invest or shied away from putting their remaining funds into speculative ventures. However, the company had also contributed to its situation. There was significant debate about the cost-effectiveness of the construction techniques, particularly the long bridge that was built across the river to move supplies. This may have been an unnecessary expenditure. Even though the dam was 80 percent complete, the power house and transmission lines had not been built. In addition, the company had not succeeded in lining up sufficient markets for its electricity. While newspapers reported that contracts had been signed with the Consolidated Gas, Electric, and Light Company and United Railways (both of Baltimore), the supply was to be relatively small—less than 15,000 total kw, or around 20 percent of the expected output ("Susquehanna Power Here in September" *Baltimore News*, February 15, 1910). It is possible that had the McCall Ferry Power Company been able to present investors with a more complete set of customers for the dam's output, it may have made the company a more desirable target for investment. The primary importance of being able to transmit and sell the energy is a central theme that will be returned to several times in the rest of this chapter.

company could no longer meet its interest payment, the bondholders of the McCall Ferry Power Company gathered together to find new investors that could finish the dam.²⁹

The Bondholders' Committee—a group of the prominent capitalists William Barnum, A. C. Bedford, Charles Coffin, S. Reading Bertron, and Gardiner Lane—began negotiations with several interested parties, ultimately agreeing to terms with a syndicate headed by John E. Aldred. Aldred had long been associated with the Shawinigan Water & Power Company, an organization that operated a large dam on the St. Lawrence River and transmitted the electricity to Montreal. According to his own recollections years later, he was aware of the developments on the Susquehanna River, watching them with interest from 1905. He had approved of the general plan but thought the company's building methods were overly costly.³⁰ He visited the site early in 1909 and agreed to raise the additional money to complete the project.

The terms of the deal were extremely favorable for Aldred and his investors. The old stock of the company was eliminated and the bonds were converted into 40 percent new bonds and 60 percent stock. In exchange for raising up to \$4,250,000 in bonds, Aldred and his new investors would receive the value of those bonds plus a bonus of \$3,500,000 in stock.³¹ Some of the original investors protested these terms, arguing that they were too generous.³² As Aldred himself noted years later, “[t]he general proposition

²⁹ Letter from Bondholders Committee to Holders of First Mortgage Bonds and Preferred Stock of McCall Ferry Power Company, December 7, 1908. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

³⁰ J. E. Aldred, “Memorandum Re: Talk by R. L. Thomas, June 6, 1935” September 13, 1935. Hagley PWP Collection, Accession 1552, Box 149, Folder 14, p. 1.

³¹ “McCall Ferry Power Company, Plan and Agreement” May 28, 1909. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

³² “Power Co. Financing Meets Opposition” *The New York Times*, June 26, 1909.

was not looked upon favorably [by the bondholders] as the plan was considered too drastic a scaling down of the securities.”³³ In exchange, the Bondholders Committee insisted that Aldred assume general management of the company and provide security for the enterprise by maintaining his interest for several years. All the new stock shares were put into a Voting Trust until 1912, preventing anyone from selling their shares before this time.³⁴ Ultimately, the bondholders agreed to Aldred’s plan, and he was appointed the Receiver of the assets and liabilities of the McCall Ferry Power Company by the Circuit Court of the United States for Eastern Pennsylvania on July 7, 1909.³⁵

Aldred had already been at work preparing to raise additional funds for the enterprise. He raised part of the money through his co-investors in the Shawinigan Water & Power Company. Two of his partners in that enterprise, Herbert S. Holt and E. R. Wood, invested enough money to warrant changing the name of the dam from McCall’s Ferry to Holtwood, a combination of their names. Aldred raised the additional money in England, working with R. M. Aitken of the Kitcat and Aitken banking house. As he recalled, capital was still tight in America and utility stocks in particular were held in low regard making it necessary to go abroad.³⁶ Most of the money was raised over the fall of

³³ J. E. Aldred, “Memorandum Re: Talk by R. L. Thomas, June 6, 1935” September 13, 1935. Hagley PWP Collection, Accession 1552, Box 149, Folder 14, p. 1.

³⁴ “McCall Ferry Power Company, Plan and Agreement” May 28, 1909. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

³⁵ *Amended Bill of Complaint, Answer, Decree Appointing Receiver and Certificate of Clerk of Court as to Entry of Bond of Receiver*, Circuit Court of the United States for the Eastern District of Pennsylvania, July 7, 1909. In *McCall Ferry Power Company Reorganization, 1908-1910*, Hagley PWP Collection, Accession 1962.

³⁶ J. E. Aldred, “Memorandum Re: Talk by R. L. Thomas, June 6, 1935” September 13, 1935. Hagley PWP Collection, Accession 1552, Box 149, Folder 14, p. 1.

1909, and by January 13, 1910, the name of the enterprise was officially changed to the Pennsylvania Water & Power Company.³⁷

Through his experience with hydroelectricity in Canada, Aldred knew that it was not enough simply to generate electricity, one had to be able to transport and sell it. He and his associates surveyed the power situation within a wide radius of the dam to identify potential markets. They saw the best opportunity in Baltimore, both because of the potential for growth and the fact that it was possible to obtain a controlling stake in the Consolidated Gas Electric & Light Company (Consolidated), which had a monopoly on the distribution of electricity in that city. Obtaining control over Consolidated would prove to be one of the most important steps in the history of the enterprise and will be discussed further in the next section.

Once the Pennsylvania Water & Power Company was incorporated and additional funds were raised, engineers and laborers renewed work on the dam and made plans to complete the powerhouse and transmission lines. Aldred brought engineer J. A. Walls with him from Shawinigan to oversee the construction. Most of the engineers associated with the McCall Ferry Power Company were let go. Over the winter and summer of 1910, the workers completed the dam by filling in the remaining open sections.³⁸ The company then built the powerhouse and installed turbines developed by the I. P. Morris Company of Philadelphia. The General Electric Company supplied the generators and the transformers were purchased from Westinghouse.³⁹ By the fall of 1910, the work on

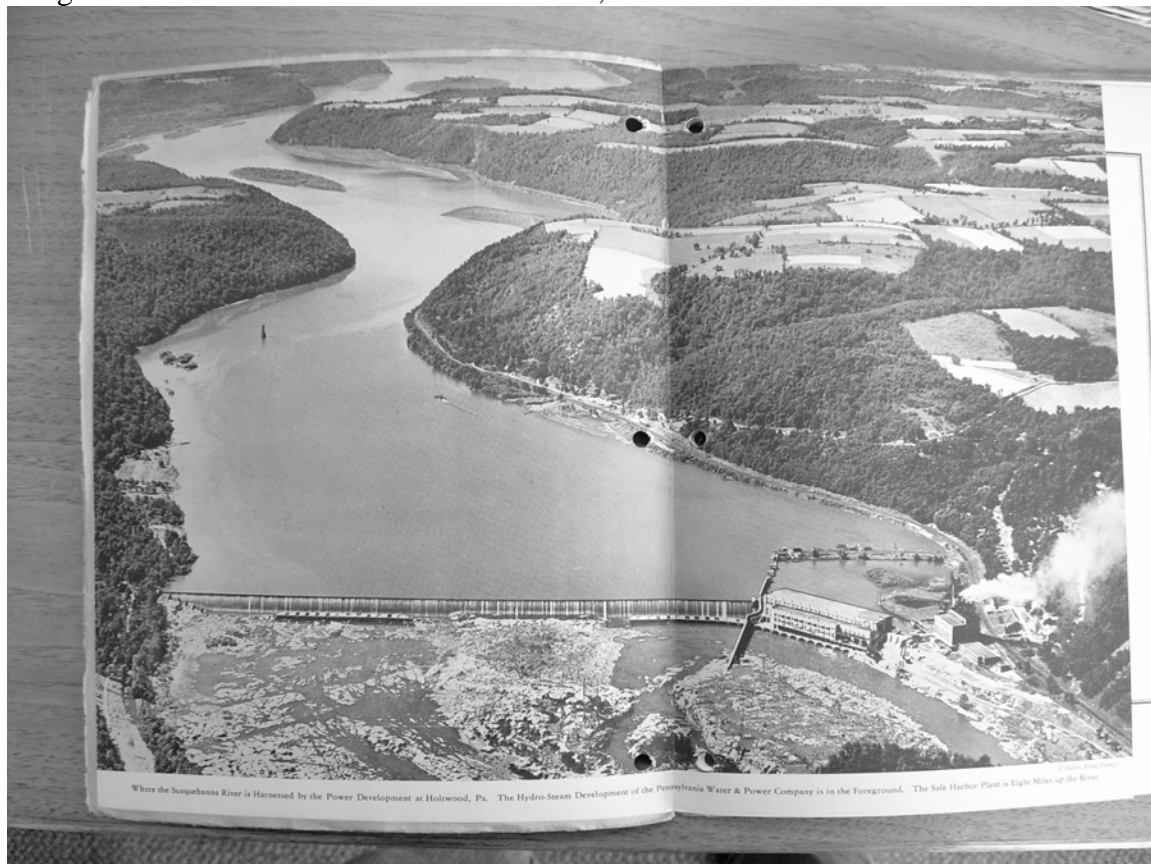
³⁷ "Certificate of Organization" Hagley PWP Collection, Accession 1552, Box 142, Folder 142, p. 1-2.

³⁸ The McCall Ferry Power Company had left fifteen forty-foot wide gaps in the dam to allow the water to flow through.

³⁹ Pennsylvania Water & Power Company, *Description and Views* (New York: E. F. Fitch, 1912).

the dam and the initial installation of powerhouse equipment was complete. Now the question became: who would buy the power and how would it be distributed?

Image 5.1: Aerial View of the Holtwood Dam, 1933⁴⁰



Finding Consumers

For most observers, the creation of a dam more than half a mile long and capable of holding back the raging waters of the Susquehanna River was the most impressive

⁴⁰ This image shows the power house on the right, the high cliffs along the lower Susquehanna, the bend in the river that pushed the ice blocks away from the power house, the raised tracks of the Columbia and Port Deposit Railroad, and the rural agricultural land surrounding the dam. The smoke is from the steam plant the company built in 1924 to supplement the hydroelectric power. Image courtesy of Hagley Museum & Library, Wilmington, DE. Image from Pennsylvania Water & Power Company, *1933 Annual Report* (Holtwood: Pennsylvania Water & Power Company, 1934). Annual reports obtained as part of Pennsylvania Water & Power Company records at the Hagley Museum & Library, Wilmington, DE. Annual reports will hereafter be cited by their year.

accomplishment of the Pennsylvania Water & Power Company. While the construction of the dam was a remarkable engineering feat, approximately 400,000 cubic yards of concrete funneling a major river through hydroelectric turbines did not guarantee financial success. In fact, as the McCall Ferry Power Company discovered, finding customers was a major challenge. It was in this capacity that Aldred's experience with hydro-electricity and financial resources proved pivotal.

At first glance, it seems surprising that it would be difficult to sell electricity. If power could be produced at a competitive cost, it would seem to follow that it would find an immediate market. However, several factors, including the monopoly power of utility companies, sunk costs, questions over supply of peak versus base power, and the variable flows of the river made it significantly more difficult for a hydroelectric company to profit from its investments. Simply put, in 1910, as today, there was no free market for electricity.

First, the company had to navigate the monopoly privileges of utility companies. By 1910, almost all consumers in the mid-Atlantic region who had access to electricity were supplied by a utility that had exclusive rights to distribute current within a specified geographic area.⁴¹ This meant that any other company, including the Pennsylvania Water & Power Company, was legally barred from selling electricity directly to consumers in these areas. The company's only practical option was to act as a wholesaler of power selling its current to utilities who would then distribute the electricity to consumers.

⁴¹ In the area surrounding the dam, the major cities were all served by a utility company with exclusive franchise rights for distributing electricity, including the Philadelphia Electric Company in Philadelphia, the Consolidated Gas Electric Light & Power Company in Baltimore, the Harrisburg Light & Power Company in Harrisburg, the Edison Electric Company in Lancaster, the Edison Company in York, and the Metropolitan Edison Company in Reading.

Therefore, the Pennsylvania Water & Power Company's possible customer base was not the tens of thousands of electricity users in the mid-Atlantic, but the handful of utility companies in the surrounding region.

While these utilities were interested in obtaining cheap electricity, they had their own sets of considerations that made procuring large blocks of hydroelectric power less desirable. Most importantly, these companies had sunk large amounts of capital into coal-fired steam plants to supply the needs of their customers. Due to the interest payments the utilities had to make on the borrowed capital, their profitability depended on using these investments at full capacity. This meant that a utility in 1910 that already had enough generating capacity to meet the needs of its customers would have little incentive to purchase additional hydroelectric power. At most, a utility would only have the financial incentive to take a few thousand kilowatts of power to support the growth of new industries. From the perspective of the Pennsylvania Water & Power Company, such contracts would not tap the full capacity of the dam or provide a sufficient return on its investment.

Second, utilities distinguished between the supply of base power and peak power. Base power was the general draw on the system that was used almost all of the time. Peak power represented the shorter periods of high use when electricity demand increased. For example, around five in the afternoon was the peak time for many utilities because factory machinery was still operating, lights were being turned on, and commuters were riding electrified streetcars. Utilities had to have sufficient capacity to provide for peak power, which meant that for most of the day, a large portion of their

generating capacity went unused.⁴² As a result, most utility companies had the financial incentive to supply their base loads with their own generating equipment and purchase supplementary peak power from a hydroelectric facility. However, such an arrangement was not desirable for the Pennsylvania Water & Power Company because it would only be selling a few hours of power a day.

To use its dam to its full capacity, the company had to sell base power to utilities. However, this was further complicated by the inconsistent flows of the Susquehanna River. The water levels varied significantly from season to season (spring usually saw the heaviest flows and summer the lightest), meaning that the actual output of the Holtwood powerhouse would vary depending on the season. Because the electricity could not be stored and base load power always had to be provided, the company could only contract for the minimum levels of output the dam would generate, not the average. This meant that most of the power generated by the dam, particularly the surplus energy in the spring, could not be included as part of base-power contracts.

Taken together, these considerations show that there were significant gaps between what utilities and the Pennsylvania Water & Power Company wanted in a contract. A utility desired supplementary peak power that would allow it to use its existing equipment at full capacity. If base power was to be supplied, the utility needed a guarantee that there would be sufficient power, even at times of low river flow. By contrast, the Pennsylvania Water & Power Company wanted to supply base load power,

⁴² This is why utilities focused on improving the load factor of the system. Their goal was to lessen the difference between base and peak power so that more of their generating equipment would be in operation more of the time. A high load factor indicated that the utility had succeeded in balancing out its power draws.

but was limited in the possible contracts it could make by the minimum level of river flow, not the maximum or even the average.

The point of this lengthy discussion of utility operations is to highlight the significance of Aldred's purchase of a controlling stake in Consolidated of Baltimore around the same time he took control of the McCall Ferry project. By purchasing control of Consolidated, Aldred could operate both Consolidated and the hydroelectric dam as a single entity. This was critical to the eventual success of the Pennsylvania Water & Power Company. On August 29, 1910, the two companies signed their first ten-year power contract.⁴³ Under the terms of the contract, Consolidated would absorb the bulk of the output of the Holtwood dam and supply the company with steam generated electricity to sell to other utilities at times of low river flow. This plan benefited both parties, but it was far more essential to the success of the Pennsylvania Water & Power Company. It gave the company the opportunity to supply large amounts of base power to the biggest local market.⁴⁴ The contract also meant that Consolidated suddenly had significant amounts of surplus steam power. This capacity could be put on hold during times of high river flow when Holtwood would supply large amounts of power and then be put into operation when the river flow was low. Being connected to Consolidated's steam power meant that the Pennsylvania Water & Power Company could then make contracts with other utilities for a greater supply of base load than would have been possible if it was solely dependent on the river to supply power. In the short term, this arrangement was not to the great advantage of Consolidated, since it did not maximize the use of their

⁴³ Pennsylvania Water & Power Company, Corporate Minutes, Volume 1, 1910-1919, Oct 14, 1910, p. 79-80. Hagley PWP Collection, Accession 1552, V 590.

⁴⁴ Philadelphia was a larger market, but it was significantly further away. Baltimore was 40 miles away, while Philadelphia was around 75 miles from the dam.

invested capital, but in the long term, it provided an outlet for Baltimore steam-generated electricity in other locations. Consolidated also gained by getting a low rate on the electricity delivered from the dam.

While there were reciprocal benefits to this contract, they would take several years of cooperative action to be realized. Without an interlocking directorate and shared management, it is difficult to imagine the companies agreeing to such a complex interaction. For example, the chief engineer of Consolidated, H. A. Wagner, opposed the contract because he thought the variable flows of the Susquehanna were less reliable than steam plants.⁴⁵ This is why Aldred spoke of the necessity of purchasing a controlling stake in Consolidated at the same time he took control of Pennsylvania Water & Power:

“One of the important elements necessary to make a success of this undertaking was the disposal of the power. After extended negotiations, contracts were made with the Consolidated Gas Electric Light and Power Company and The United Railways and Electric Company of Baltimore. In order to make possible the first and most important of these contracts, it was necessary for me to purchase control of the Consolidated Gas Electric Light and Power Company of Baltimore, which involved raising several million dollars.”⁴⁶

By the spring of 1910, Aldred was elected President of both Consolidated and the Pennsylvania Water & Power Company, greatly facilitating the signing of a complex power-sharing agreement. Moreover, several of his syndicate, including Wood, Holt, and Charles Clarke, were elected to both boards.⁴⁷ As he stated to the dam company’s Board of Directors, the purchase of control assured “close and harmonious relations.”⁴⁸ This

⁴⁵ Thomson King, *Consolidated of Baltimore, 1816-1950: A History of Consolidated Gas Electric Light and Power Company of Baltimore* (Baltimore: Consolidated Gas Electric Light and Power Co., 1950), 184.

⁴⁶ J. E. Aldred, “Memorandum Re: Talk by R. L. Thomas, June 6, 1935” September 13, 1935. Hagley PWP Collection, Accession 1552, Box 149, Folder 14, p. 2.

⁴⁷ “Baltimore Lighting Combination” *Wall Street Journal*, Oct 5, 1910.

⁴⁸ Pennsylvania Water & Power Company, Corporate Minutes, Volume 1, 1910-1919, Jan 14, 1910, p. 20-2. Hagley PWP Collection, Accession 1552, V 590.

comprehensive power selling and sharing agreement was the most important step in the eventual financial success of the hydroelectric dam.

The Pennsylvania Water & Power Company also made a contract with The United Railways and Electric Company (United Railways) of Baltimore, the city's electric streetcar company. Negotiations began as early as July of 1910, but were not completed until 1911.⁴⁹ By 1912, United Railways had over 400 miles of track and 800 cars in its system, operating all the streetcars within 17 miles of Baltimore. The contract was signed on February 11, 1911 and reportedly called for an initial supply of 16,000 hp (electricity sales used both horsepower and kilowatts as units of measurement. 1 kw is approximately 1.33 hp).⁵⁰ This contract also included a power-sharing clause whereby the new steam generating stations of United Railways would be available to the Pennsylvania Water & Power Company at times of low river flow.⁵¹

The difference between owning a controlling stake in the companies and operating as independent entities can be seen from a comparison of the contracts the Pennsylvania Water & Power Company and McCall's Ferry Power Company made with the Baltimore companies. The McCall's Ferry Power Company had signed contracts with Consolidated and United Railways as early as 1907, but these contracts were for small amounts of power. While exact details are not known, newspaper articles reported that the total was around 10,000 kw for Consolidated and 4,000 kw for United Railways. The contracts Pennsylvania Water & Power made allowed a much greater percentage of

⁴⁹ "Pennsylvania Water & Power Company," *Electrical World* 56, no. 3 (1910).

⁵⁰ Pennsylvania Water & Power Company, Corporate Minutes, Volume 1, 1910-1919, Feb 10, 1911, p. 83-5. Hagley PWP Collection, Accession 1552, V 590, Pennsylvania Water & Power Company, *First Annual Report*, 1910.

⁵¹ Pennsylvania Water & Power Company, *Description and Views*.

the dam's output to be sent to Baltimore, starting with 25,000 kw and allowing for increases of up to 100,000 kw.⁵² This difference between supplying small amounts of power versus a large percentage of the base load was a significant factor in the financial success of the latter organization.

The integration of the Holtwood Dam into a network with the coal-fired electricity plants of Consolidated and United Railways marked a further departure from the organic economy. The variable flows of the river could not supply the consistent and ever-increasing power needed by the region's electrical consumers. By supplementing the river's flows with fossil fuel energy, the Holtwood dam became part of an electrical network characteristic of the mineral economy.

Lancaster was the third major customer for Holtwood's power. Lancaster was interested in receiving hydroelectricity early on because the local utility, the Edison Electric Company, had generating plants that were not in good operating condition. As early as 1910, the Pennsylvania Water & Power Company reported in its annual report that a contract had been agreed to supply Lancaster with power and only needed formal confirmation.⁵³ Apparently this formal confirmation never happened. By June 16, 1911, the Board of Directors authorized Aldred to suspend negotiations with Edison Electric due to a failure to reach an agreement.⁵⁴ By June of the following year, the Board of Directors approved resuming negotiations and a contract was signed on October 9,

⁵² "Susquehanna Power Here in September" *The Baltimore News*, February 15, 1910. Hagley PWP Collection, Acc 1962, *Pennsylvania Water & Power Company Scrapbook # 1*. Note: this article gives information on both contracts.

⁵³ Pennsylvania Water & Power Company, *1910 Annual Report*.

⁵⁴ Pennsylvania Water & Power Company, *Corporate Minutes*, Volume 1, 1910-1919, p. 88-9. Hagley PWP Collection, Accession 1552, V 590.

1912.⁵⁵ In its 1912 Annual Report, the company announced that a ten-year contract had been signed and would go into effect on May 1, 1913. Pennsylvania Water & Power would supply practically all the power needs of Edison Electric using both hydroelectricity and steam power from Consolidated during times of low river flow.⁵⁶ Once again, it is important to note that signing a contract for all of Lancaster's power needs was dependent upon the initial contract with Consolidated that gave the dam company access to steam power at times of low river flow. The Edison Electric Company took responsibility for building the twenty-mile transmission line from Lancaster to Holtwood. This contract was the first step towards the development of a regional power network that went beyond supplying Baltimore.

Even with these three contracts signed, the nature of the Susquehanna River and the variable demands of electric utilities for power meant that Pennsylvania Water & Power still had excess capacity, particularly during times of high river flow and at non-peak load times. To utilize this power, the company decided to create an electro-chemical plant that could be supplied with this cheap power when demand from other consumers was low. Aldred had already tried this strategy successfully with his Canadian hydro-development project. In 1915, Pennsylvania Water & Power formed the Shawinigan Electro-Products Company to manufacture ferro-silicon, a raw material important in steel manufacture. With an initial installation of a 10,000 hp furnace, the company noted that the plant would generated \$150,000 in earnings from electric usage alone. The dividends from sales of ferro-silicon would go to company stockholders as

⁵⁵ Pennsylvania Water & Power Company, Corporate Minutes, Volume 1, 1910-1919, p. 101-3, 109. Hagley PWP Collection, Accession 1552, V 590.

⁵⁶ Pennsylvania Water & Power Company, *1912 Annual Report*.

well.⁵⁷ At first, this was a very successful venture, especially as ferro-silicon was important for the war effort. The plant's capacity was expanded to 30,000 hp in 1917, when the company reported that it would use 100,000,000 kwh that would have otherwise gone unused.⁵⁸ With the end of the war, there was a glut of ferro-silicon on the market and the total output decreased significantly. By 1919, the plant was barely in operation.⁵⁹ Although the company continued to exist for several years, its relative importance seems to have diminished as it ceased to be mentioned in Annual Reports or Corporate Minutes.

It is also important to note where power did not go. There were several other sites of significant electricity consumption within a hundred miles of the dam for which contracts could not be negotiated, including Philadelphia, Wilmington, Harrisburg, and Reading. The fact that arrangements could not be made to sell excess power to these sites demonstrates that simply having the capacity to produce electricity did not mean it would get used or paid for. The network of customers created by Aldred was not simply the set of largest and nearest utilities. The energy landscape of the Susquehanna River was determined by financial interrelationships and prior technological investments, not geographical proximity.

Transmitting Energy

Customer contracts were necessary to the financial success of a hydroelectric enterprise, but only if the power could be transported many miles from the dam cheaply

⁵⁷ Pennsylvania Water & Power Company, *1915 Annual Report*, 6-7.

⁵⁸ Pennsylvania Water & Power Company, *1916 Annual Report*.

⁵⁹ Pennsylvania Water & Power Company, *1919 Annual Report*.

and reliably. Without wires connecting Holtwood with its customers, the output of the dam would have been trapped at the site of production. The transmission wire network of the Pennsylvania Water & Power Company made it possible for the power of the river to support the extension of an urban and industrial society many miles away. By studying these wires, we get a better sense of how the system as a whole worked.

When Pennsylvania Water & Power turned its attention to transmitting power to Baltimore at the beginning of 1910, it planned to create the longest high-voltage line on the eastern seaboard. Fortunately, it could draw on earlier precedents and engineering knowledge that made the project more feasible. At this time, California led the nation in the development of high-voltage transmission wires. Hydroelectric resources in the Sierra Nevada Mountains were aggressively pursued as a way to provide power to growing cities such as San Francisco and Los Angeles. For example, as early as 1901 the Bay Counties Power Company had constructed a 140-mile transmission line from the Sierra Nevada mountains to Oakland.⁶⁰ In addition to knowledge from other parts of the nation, several of the engineers Aldred brought to Holtwood including J. A. Walls had prior experience operating transmission wires from Shawinigan Falls to Montreal.

As soon as Aldred acquired control of both the Holtwood Dam and Consolidated in 1909, it was a foregone conclusion that power would be sent to Baltimore. Company engineers soon began to acquire many of the necessary rights-of-way for the transmission line.⁶¹ The company desired to have a one hundred-foot wide right of way for the forty-mile route to Baltimore. The relatively wide strip of land would allow the company to

⁶⁰ Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*, Chapter X.

⁶¹ They were assisted in this effort because the McCall Ferry Power Company had purchased many of the necessary rights in anticipation of contracts with Consolidated and United Railways.

build several transmission lines along the right of way and to keep trees away, thereby mitigating the risk that they would fall on the line and interrupt service.

Obtaining rights-of-way was not a simple process. Utility companies, despite the efforts of the McCall Ferry Power Company and Aldred, did not have general eminent domain privileges.⁶² Moreover, the Pennsylvania Water & Power Company's charter did not grant it privileges to operate over a large geographic area. Therefore, the management team created three subsidiary companies to build the transmission lines: the Pennsylvania Transmission Company in York County, PA; the Susquehanna Transmission Company in Baltimore County, MD; and the Susquehanna Pole Line Company in Harford County, MD.

For most practical purposes, the fact that these were separate companies was just a legal matter that did not influence actual operations. However, there was one notable exception. The Susquehanna Pole Line Company in Harford County, MD had a special corporate charter that gave it eminent domain privileges.⁶³ This right allowed the Susquehanna Pole Line Company to force owners to sell them rights-of-way across private lands at court-ordered prices. This quickly drew the ire of landowners who either opposed the presence of high-voltage transmission wires across their property or wanted

⁶² For example, there was a bill introduced to the Pennsylvania legislature in 1909 that sought to give utilities eminent domain privileges. Newspapers reported that the McCall Ferry Power Company was behind the efforts and would be the primary beneficiary ("Combine to Control Electric Power" *Philadelphia Public Ledger*, January 19, 1909). Aldred was said to be pushing for similar legislation a few months later after he took control of the project ("Electric Eminent Domain" *Philadelphia Public Ledger*, March 31, 1909). However, a general ruling on eminent domain was not issued during this period, in no small part because some utilities opposed the bill. For example, the Philadelphia Electric Company was opposed to these bills because it feared that it would make it easier for the hydroelectric dam company to cut into its business in the towns surrounding Philadelphia.

⁶³ "Poles and Wires Win" *Baltimore American Star*, Feb 4, 1910. How the company got this privilege is unclear. In all likelihood, a previous group of entrepreneurs, perhaps associated with one of the early efforts to develop the hydro-electricity along the Susquehanna, had successfully petitioned the state legislature for a special charter and then went out of business. For whatever reason, most likely the failure of the previous enterprise, Aldred was able to acquire this charter.

to receive higher levels of compensation. However, the courts upheld the transmission company's rights.⁶⁴ By contrast, in York and Baltimore counties, the subsidiary companies had to pay higher rates to landowners for the right-of-way. In all the counties, the companies needed to apply to the County Commissioners for permission to cross public highways.⁶⁵

Despite these subtle differences between the subsidiary companies, they were all under the direction of the Pennsylvania Water & Power Company. By the summer of 1910, the company had acquired the rights-of-way in York and Harford counties, but was having difficulty getting the remaining rights in Baltimore County.⁶⁶ Finally, by the end of August, it was reported that the final property rights had been attained.⁶⁷

At the same time the company was working to acquire the line, it also made its decisions on materials. As was common on long-distance transmission wires, the company opted for steel towers instead of wooden poles. Steel towers were more reliable and could support heavier cables, thereby justifying the additional construction expenses. This was especially important as it was common for alternating current to be separated into three phases, each of which was shipped over its own wire. A circuit consisted of the three wires put together, and a transmission wire usually referred to one or two circuits. The company contracted with the Milliken Company to design steel towers capable of supporting two circuits or a total of six wires. Second, the company chose to

⁶⁴ For example, landowners J. Edward and Dora Webster sued the company in the Circuit Court of Harford County, but lost the case. In February, 1910 the Court of Appeals maintained the verdict. ("Poles and Wires Win" *Baltimore American Star*, February 4, 1910.) Two weeks later, the company began condemnation proceedings against William J. Barton and Hugh C. Whiteford. As a newspaper noted, "It is understood that similar steps will be taken in other cases where the company and landowners cannot get together on figures." ("No Title" *Bel Air Aegis*, May 18, 1910).

⁶⁵ "Franchise Asked For" *Harford Democrat*, April 29, 1910.

⁶⁶ "Susquehanna Transmission Company," *Electrical World* 56, no. 4 (1910).

⁶⁷ "Mccall Ferry-Baltimore Transmission Line," *Electrical World* 56, no. 8 (1910).

use aluminum wires wrapped around a steel core. Copper was the most common material for transmission wires at the time due to its high levels of conductivity.⁶⁸ However, aluminum was lighter than copper, had a higher melting point which was beneficial at high voltages, and only cost slightly more per pound.⁶⁹ Because aluminum was lighter, each wire could hold 19 strands, thereby giving the circuits a normal capacity of 16,000 kw and a maximum capacity of 40,000 kw.

Finally, the company had to decide on the line's operating voltage. Higher voltages were more desirable because they resulted in lower energy losses during transmission. For example, the energy loss over forty miles on a 66,000-volt line was estimated to be 1/40th the loss on an 11,000-volt line.⁷⁰ On the other hand, increasing the voltage of the electricity required transforming the electricity ("stepping it up" at the generating station and "stepping it down" at the receiving station). Some electricity was lost as the voltage was increased or decreased, and a company also had to invest in machinery to perform these tasks. Higher voltage electricity was also more difficult to manage and needed more insulators along the transmission route. Therefore, company engineers had to find the right balance between energy losses in transmission and the

⁶⁸ A survey of 55 transmission wires built before 1915 shows that 41 lines were made of copper, 3 combined copper and aluminum, 9 were built with aluminum, and 2 did not report the wire material. Two of the nine companies using aluminum wires were the Pennsylvania Water & Power Company and Shawinigan Water & Power Company "Transmission Systems of the World Operating at and above 70,000 Volts, Ranked According to Operating Voltage," in *Census of Electrical Industries: Central Electric Light and Power Stations and Street and Electric Railways, 1912* (Washington: Government Printing Office, 1915).

⁶⁹ Aluminum had about 60 percent of the conductivity and 60 percent of the weight of copper. National Electric Light Association, *Handbook on Overhead Line Construction* (Philadelphia: National Electric Light Association, 1914). Its cost was reported in 1910 to be "not very much greater" than copper: "Aluminum Versus Copper Cables," *Electrical World* 56, no. 24 (1910). "Aluminum Conductors," *Electrical World* 56, no. 7 (1910).

⁷⁰ Pennsylvania Water & Power Company, *Holtwood Power Development* (Holtwood: Pennsylvania Water & Power Company, 1922), 16.

financial costs of stepping the energy up and down. They ultimately decided to operate the line at 70,000 volts.

With these decisions complete, workers began actual construction of the line. The first step was to build the steel towers, each of which was fifty to a hundred feet high and about five hundred feet apart. By the summer, several hundred men were at work. Construction teams were generally composed of a foreman, linemen, and grunts. Linemen were skilled workers who climbed the towers as they were being built and connected the steel beams. Grunts were responsible for hauling the materials and hoisting the beams to the linemen. The men lived in tents along the path of the wire and moved camp as they made progress.⁷¹

The labor of building a transmission line was not easy. The erection of steel towers was physically demanding under the best conditions. The steel bars for the towers needed to be hoisted into place using ropes and pulleys. To provide foundations for the towers, the men drilled holes in rocks and poured concrete foundations. Under good conditions, a team could erect a tower in a day or two. However, if the land was uneven or the ground was marshy, it could take up to a week for a single tower. The supplies had to be hauled to the area by men and animals since most of the path ran through rural fields. There was also danger: a worker could fall off a tower, be struck by a tool dropped by a lineman, or be injured dynamiting ground rock to create a base for the

⁷¹ The work dynamics of a camp of wire workers is vividly described in a novel by William Wister Haines, a former lineman who was reported to have worked on transmission wires in the mid-Atlantic in the 1920s. William Wister Haines, *Slim* (Boston: Little, Brown, and Company, 1934).

tower. One of the workmen, a man named Evans Vickers from Delta, PA, died when a dynamite stick exploded as he approached a tower base.⁷²

As the company was overseeing construction of the steel towers, it also built transformer stations at the beginning and end of the line. The wires began at a substation on the island between the York and Lancaster side of the river. Here the electricity was stepped up from 11,000 volts to 70,000 volts. The company bought a piece of property from Consolidated on the outskirts of Baltimore and built a second transformer station (Highlandtown) that reduced the voltage of the line to 11,000 volts.⁷³ From this substation, Consolidated shipped the electricity to its other substations and further reduced the voltage as it was distributed to end customers.

By the end of July, the steel towers had been erected in York County and the northern section of Harford County.⁷⁴ The remaining towers were built over the next two months. The final step was to string the wires. First the men installed a grounding wire along the top of the steel towers for lightning protection. For the installation of two circuits, a small group of men traveled the length of the line, uncoiling the six aluminum wires and connecting them to the steel towers. Each wire was separated from the steel tower by three feet of porcelain insulators.

By October, the line was complete and the company was ready to begin service. On October 14th, Mayor Mahool of Baltimore touched a knob in the powerhouse at the dam and electricity began coursing through the line. It was reported that lights were

⁷² According to newspaper reports, Vickers had planted three sticks of dynamite to remove rocks for the base of a tower. He approached the tower after the initial explosion, but apparently the third stick of dynamite had not yet blasted. It went off as he neared the tower, killing him instantly. "Fatal Accident on New Power Line" *The Aegis*, June 10, 1910.

⁷³ Pennsylvania Water & Power Company, *Holtwood Power Development*, 16.

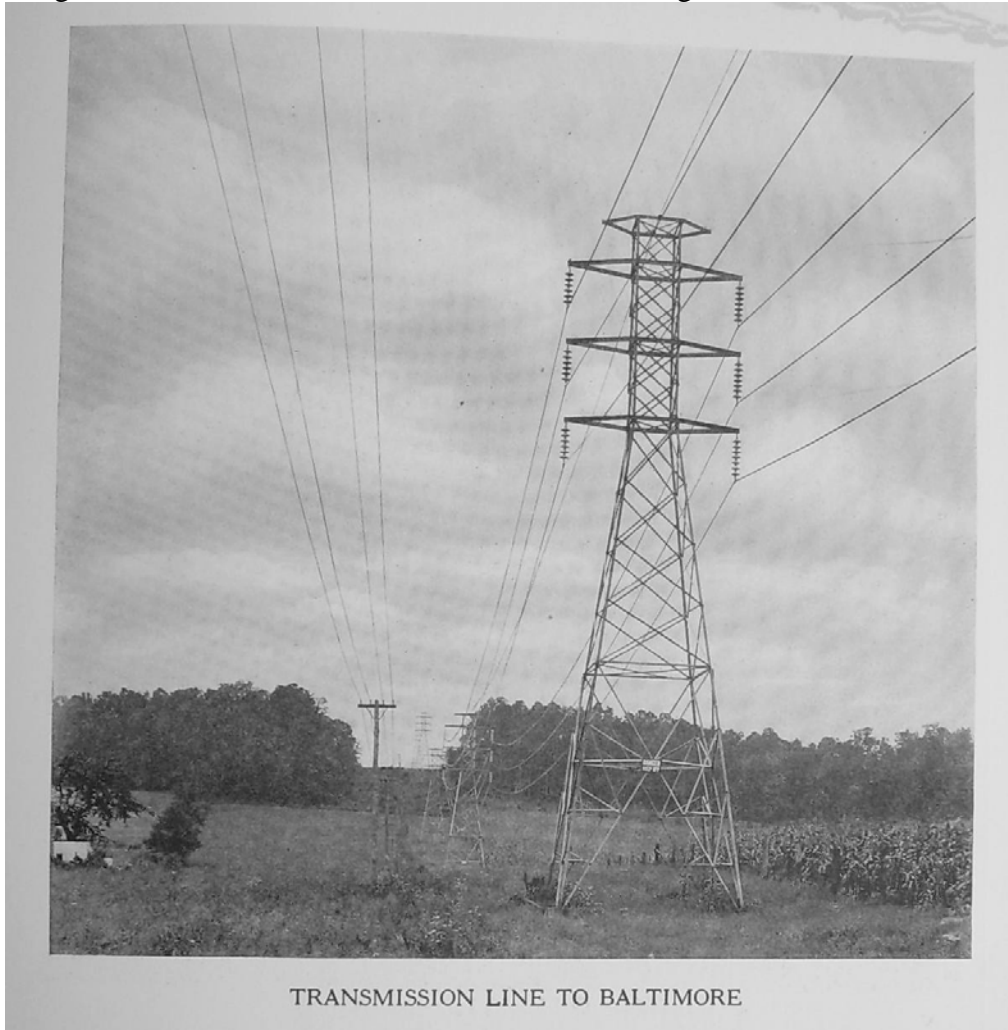
⁷⁴ "Susquehanna Transmission Company."

burning in the Baltimore substation before the spectators were able to begin applauding.⁷⁵ The flowing water of the Susquehanna could now power lights, run streetcars, and operate machinery several miles away.

Although the construction of the Holtwood Dam drew the most comment from contemporary observers, the creation of a transmission line network was as critical to the ultimate success of the venture. The fact that the transmission wires allowed the energy to travel instantaneously to Baltimore's homes and factories with only small losses meant that the energy of the Susquehanna River was no longer restricted to the riverbed. As had happened with coal canals and oil pipelines, transport infrastructure enabled a geographic separation between the sites of energy production and consumption. A new energy landscape had been created.

⁷⁵ "Susquehanna Power In Use" *New York Times*, October 15, 1910.

Image 5.2: Transmission Wire to Baltimore, Showing 2 Circuits⁷⁶



Putting the System to Work

With the creation of the dam, powerhouse, transmission lines, and customer contracts, the Pennsylvania Water & Power Company was ready to turn the estimated thirteen million dollar investment into a productive enterprise.⁷⁷ The company soon began to ship large amounts of electricity to its customers. By 1916, the company

⁷⁶ Image courtesy of Hagley Museum & Library, Wilmington, DE. Pennsylvania Water & Power Company, *Pennsylvania Water and Power Company* (New York: Pennsylvania Water & Power Company, 1913[?]), 25.

⁷⁷ "Pennsylvania Water & Power Company."

produced 420,000,000 kwh, which was over 14 percent of the electricity generated by utilities in Pennsylvania and 3 percent of the hydroelectric power produced nationally.⁷⁸

The company was able to supply the entire needs of the city of Lancaster, a majority of the power in Baltimore, and had enough left over to operate a ferro-silicon factory.

Baltimore was the first and primary market for the company's hydroelectricity. Consolidated absorbed the lion's share of the Holtwood dam's output, which provided more than half of Baltimore's electric supply for the period. During the 1910s, hydroelectricity made up nearly two-thirds of Consolidated's energy, and just under half in the following decade (see Table 5.1). In addition, the company sent a considerable amount of electricity to Baltimore that United Railways used for its streetcar service.

Table 5.1: Consolidated Steam versus Hydro Electricity, 1910-1929⁷⁹

	Electric output	Steam generation	Hydro power purchased	% of total output from hydro
1910-1914	524,698,746	137,477,583	387,491,163	73.81
1915-1919	1,588,413,815	611,918,635	976,495,180	61.48
1920-1924	2,739,137,068	1,441,974,768	1,297,162,300	47.36
1925-1929	4,044,206,887	2,240,636,305	1,803,570,582	44.60

The delivery of electricity from the Susquehanna River to Baltimore coincided with, and no doubt contributed to, a period of major industrial growth for the city. Ever since a fire had destroyed much of Baltimore's downtown in 1904, its citizens and boosters had felt the city's industrial growth was not keeping pace with other urban centers. Because he believed that a healthy Baltimore economy would be profitable to both Consolidated and Pennsylvania Water & Power, Aldred spearheaded an industrial

⁷⁸ Holtwood Dam output from Pennsylvania Water & Power Company, *1916 Annual Report*. Pennsylvania utility production in 1917 and national hydroelectric production from United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1922* (Washington: Government Printing Office, 1925), 32-3, 45.

⁷⁹ Consolidated Gas Electric Light & Power Company, *1934 Year Book* (Baltimore: Consolidated Gas Electric Light & Power Company, 1935), 17. Accessed at Harvard Baker Library. Hereafter cited as Consolidated, *Annual Report*.

survey of the city in 1914 that sought to identify opportunities for growth. The opening of the report noted that not all was well: “The one clear and emphatic impression left upon our minds by the data hereinafter presented is that the industrial growth of Baltimore has been less pronounced than it should have been, having in mind the general economic progress of the country and the forward strides of other cities no more favorably circumstanced.”⁸⁰ Given Baltimore’s advantages in location and access to natural resources, the report noted that much better progress could be achieved if businessmen actively supported new enterprises. The survey inspired Baltimore businessmen to create The Industrial Corporation, an agency designed to provide capital and support to new business enterprises.⁸¹

The efforts of the new organization, along with cheap power from the Susquehanna, contributed to an industrial resurgence over the next couple decades. When Consolidated sponsored a new industrial survey twenty-five years later, the report noted: “The progress of the City during this period has been nothing short of remarkable, its industrial growth far surpassing that of competing cities on the Atlantic Seaboard and its rank among the industrial centers of the United States, based on value of manufactures, advancing from eleventh to seventh.”⁸² Baltimore’s industrial output grew from just under 300 million dollars to more than 925 million dollars from 1914 to 1937. Moreover, its industrial output had actually grown despite the Depression conditions

⁸⁰ J. Edward Aldred and Ernest V. Illmer, *Industrial Survey of Baltimore* (Baltimore, Md.: 1915), v.

⁸¹ King, *Consolidated of Baltimore, 1816-1950: A History of Consolidated Gas Electric Light and Power Company of Baltimore*, 208.

⁸² Industrial survey of Baltimore and Consolidated Gas Electric Light and Power Company of Baltimore, *Second Industrial Survey of Baltimore. A Quarter Century of Progress in the City of Industrial Advantages, 1914-1939* (Baltimore: Consolidated Gas Electric Light and Power Company of Baltimore, 1939), 18-9.

whereas other seaboard cities such as New York, Philadelphia, and Boston had experienced declines.⁸³

Consolidated played an important role in stimulating this growth, serving more than 3,300 industrial customers with over 425,000 hp of installed motors by 1924. 153 companies in the metal industry had installed 130,773 hp of electrical capacity, 29 railroad and railway companies used 45,771 hp, 17 fertilizer companies used 21,652 hp, and 18 shipbuilding companies used 18,348 hp. Other industries using significant quantities of electricity included textiles, ice and refrigeration, stone and concrete, woodworking, paper, office buildings, butchers, bakers, glass, and electrical equipment.⁸⁴ By 1931, Baltimore's residential customers used nearly 20 percent more electricity and paid 3 percent less than the average residential customer for the nation as a whole.⁸⁵ Baltimore homeowners used more electricity than Philadelphians as well, consuming on average 585 kwh versus 499 kwh in 1929.⁸⁶

Lancaster also benefited from access to power from the Susquehanna. Beginning in 1913, the Holtwood dam provided nearly all the power distributed by the Edison Electric Company. The demand in that year was just under 25,000,000 kwh. By 1936, the demand for electricity exceeded 166,000,000 million kwh, an increase of 650 percent in just over twenty years. Once known for its rich agricultural heartland, Lancaster also developed into an important industrial center using electricity in industries including machine shops, fertilizer, bakeries, textiles, ice, glass, cork, dairies, linoleum, and

⁸³ Ibid., 18.

⁸⁴ Consolidated, *1924 Year Book*, p. 20.

⁸⁵ Consolidated, *1931 Year Book*, p. 4.

⁸⁶ King, *Consolidated of Baltimore, 1816-1950: A History of Consolidated Gas Electric Light and Power Company of Baltimore*, 271; Nicholas B. Wainwright, *History of the Philadelphia Electric Company, 1881-1961* (Philadelphia: Philadelphia Electric Company, 1961), 253.

hardware.⁸⁷ As was characteristic of the mineral economy, this industrial growth occurred without requiring the region to decrease its agricultural output—more and more was possible.

The final outlet for power was the Shawinigan Electro Products Company. The factory was built in 1915 with one 10,000 hp electric furnace capable of producing 30 tons of ferro-silicon a day, or about 10,000 tons per year. The next year, the company tripled the plant's capacity to 30,000 hp, due to the high demand for steel during the First World War. The electrical consumption of the plant was remarkable—about 55,000,000 kwh in 1916, nearly 100,000,000 in 1917, and 60,000,000 in 1918.⁸⁸ To put this consumption into context, a single factory used more electricity than the entire load of Lancaster and nearly a third of Baltimore, one of the nation's largest cities. Given the huge electricity inputs to the creation of materials such as ferro-silicon or aluminum, it is clear that the production of these materials was only possible within the context of energy superabundance.

As Pennsylvania Water & Power increased its supply of electricity to its various markets, it had to expand both its production facilities and its transmission wire network. For example, the company added new generators to the hydroelectric plant. When the powerhouse was completed in 1910, it was designed for a total capacity of ten generators, but the company had only installed the hardware for the first five units by 1911. This was a pragmatic financial move, since each generator cost a significant amount of money to install and it was not worth incurring the interest charges until it was clear that the power could be sold. As it turned out, the company also benefited when improvements in

⁸⁷ Pennsylvania Water & Power Company, *1936 Year Book*, 30.

⁸⁸ Pennsylvania Water & Power Company, *1918 Annual Report*.

generator capacity allowed them to install more efficient turbines. The initial capacity of each generator installed in 1910 was 7,500 kw. By 1911, the capacity of each generator had been increased to 10,000 kw, and the sixth unit in 1912 was rated at 12,000 kw.⁸⁹ The seventh unit was installed in 1913, the eighth in 1914, and units nine and ten in 1924.

In 1924, the company decided to supplement its hydroelectricity with a steam power plant that could be used during times of low river flow. For fuel, the company decided to take advantage of an unintended consequence of its dam construction. Since being built, the lake that formed behind the dam had operated as a settling basin for anthracite coal dust from the collieries upstream. By dredging the mixture of sand and coal from the lake bottom and separating it into low-grade coal, the company found a cheap and available fuel for its steam plant. By summer of 1925, the company had an additional 30,000 hp of steam capacity supplementing the flow of the river.⁹⁰ A river survey conducted by the company in 1931 estimated that there were more than ten million tons of recoverable anthracite coal in the lake bed, enough to power the plant for several decades.⁹¹

As with other examples of transport infrastructure, the company's transmission network required maintenance and expansion over time. From the beginning the company employed a number of men to patrol the transmission line to ensure it remained in working order. In addition, as Baltimore increased its electricity demand, the transmission losses on the initial two circuits began to increase. Therefore, the company

⁸⁹ Pennsylvania Water & Power Company, *Description and Views*.

⁹⁰ Pennsylvania Water & Power Company, *1925 Annual Report*.

⁹¹ Pennsylvania Water & Power Company, *1931 Year Book*.

added another steel tower capable of handling two more circuits along its right of way in 1914. One circuit of wires was added in 1914 and the other in 1917. The company also expanded the Highlandtown substation to be able to handle the additional flow of electrons, increasing the station's capacity to 94,000 hp of electricity. The company noted that the efforts would cost around \$400,000 but pay for itself very quickly in decreased line losses.⁹² Within a year, the new wires had already reduced transmission losses by 2.5 percent.⁹³

The company also worked to make the lines more reliable. Lightning was the biggest source of disruptions. In the line to Baltimore's first full year of operation, there were 23 interruptions due to lightning strikes. Between 1911 and 1917, lightning caused an average of 5.8 outages per year.⁹⁴ One way of mitigating the effect of lightning was to run two wires at the top of the steel tower that were designed to catch the lightning and run it to the ground. In addition, the company installed Nicholson's fuse lightning protection apparatus. The device automatically removed the voltage from the transmission line when a lightning flash was detected and immediately restored service afterwards.⁹⁵

Aldred also sought new markets for the company. In the early 1920s, there were several discussions about the possible development of an integrated power system connecting the utilities of the eastern seaboard. The first was the Superpower system proposed by William S. Murray, who envisioned a series of long transmission wires linking large generating stations between Washington D.C. and Boston thereby creating

⁹² Pennsylvania Water & Power Company, *1913 Annual Report*.

⁹³ Pennsylvania Water & Power Company, *1914 Annual Report*, 7.

⁹⁴ Pennsylvania Water & Power Company, *1940 Annual Report*, 39-41.

⁹⁵ Pennsylvania Water & Power Company, *Pennsylvania Water and Power Company*, 35.

an integrated network on the eastern seaboard.⁹⁶ Pennsylvania Water & Power was a strong early proponent of this system, largely because it offered the company more outlets for peak hydroelectric power that currently went unsold. The more the company was integrated into regional transmission grids, the more power it could sell. By 1921, the company was providing information to the Superpower survey and by the following year was proclaiming Holtwood to be ideally located for such a system in its promotional literature.⁹⁷ Although a government initiated Superpower system never came to fruition, Pennsylvania Water & Power was supportive of the move towards regional integration of power distribution.

While supporting the Superpower proposal, the company took matters into its own hands and expanded its network by signing new contracts in 1923 with the Edison Light & Power Company in York, PA and the Chester Valley Electric Company in Coatesville, PA. To supply these customers with electricity, the company built 70,000-volt transmission lines to each of the cities that could later be expanded to 110,000 volts if integrated into a wider network. While neither of these contracts called for power deliveries comparable to the arrangements with Baltimore or Lancaster, they provided the company with a wider power market and an expanded network. The company saw this as an advantageous strategy since it positioned them to be a more central player in any Superpower network. The transmission line to Coatesville was also strategic. It ran on a path directly from the dam towards Philadelphia, making a future interconnection with the Philadelphia Electric Company easier to implement.

⁹⁶ Murray's Superpower proposal is discussed in greater depth in the next chapter.

⁹⁷ "Memorandum – Discussion with Dr. C. T. Hutchinson, This Morning" November 17, 1921. Hagley PWP Collection, Accession 1962, Box 32, Correspondence & Data exchanged with Dr. C.T.H. and notes on Discussions; Pennsylvania Water & Power Company, *Holtwood Power Development*.

Finally, in 1930, the company began construction of a new hydroelectric dam eight miles north of Holtwood at Safe Harbor. Company engineers had been considering a second dam since at least the 1910s, and by the end of the 1920s believed there was sufficient demand to justify the construction of a 255,000 kw dam, more than twice the capacity of Holtwood. Pennsylvania Water & Power and Consolidated jointly financed the project and ground was broken in April of 1930. Due to a fortuitous combination of cheap labor due to the start of the Great Depression and a year of low river flow, the dam was completed ahead of schedule by December of 1931. Most of the power was absorbed by Consolidated while the Pennsylvania Railroad, which was in the process of electrifying its railroad lines between Washington, DC and New York, consumed much of the rest of the output.⁹⁸

The companies constructed a series of new transmission wires to distribute the output. These included a 70-mile set of 220,000-volt wires to the Westport substation on Baltimore's west side built in 1931, a 32-mile 132,000-volt transmission wire from Safe Harbor to Perryville, MD (near Havre de Grace) to supply the Pennsylvania Railroad, and a 70,000-volt line connecting the Safe Harbor and Holtwood dams. In addition, Consolidated built a 60-mile 220,000-volt line from Baltimore to Washington D.C. to provide an interchange with the Potomac Electric Power Company.⁹⁹

The expansion of its system led to financial rewards. The company began paying dividends in 1914 at a rate of 1 percent quarterly and increased this rate to 1.75 percent

⁹⁸ Pennsylvania Water & Power Company, *1931 Annual Report*.

⁹⁹ Pennsylvania Water & Power Company, *1932 Annual Report*.

by 1921.¹⁰⁰ In May of 1927, the company decided to eliminate the par value of its stock (which had previously been \$100) and issue four shares for every previous share.¹⁰¹ The dividends had been paying at 2 percent quarterly prior to the split, and in 1930, the new dividend rate was \$3 per share (comparable to 3 percent quarterly under the old share). By 1931, the price of a share was selling on the New York Exchange at around \$63 in 1931, giving original stockholders a tidy profit.¹⁰² By 1936, in the midst of the Great Depression, the dividend rate was increased to \$4 per share and it would reach \$5 per share in 1939.¹⁰³

Two things are notable about the supply of electricity shipped from the Susquehanna to these locations. The first is that the transmission wires enabled the building up of energy-intensive enterprises at locations far away from the site of energy generation. Instead of moving people and industries to the Susquehanna River, the transmission wires made it easy to move the power of the Susquehanna River to cities. Second, once each location got access to cheap and abundant electricity, it triggered a pattern of steady growth. Lancaster, a mid-sized city, was using more power in 1923 than Consolidated supplied to Baltimore just eleven years before.¹⁰⁴ Consolidated's output grew at a similar rate, from just over 125 million kwh in 1914 to 1,300 million

¹⁰⁰ Pennsylvania Water & Power Company, *1914 Annual Report*, Pennsylvania Water & Power Company, *1921 Annual Report*.

¹⁰¹ Pennsylvania Water & Power Company, *1927 Annual Report*.

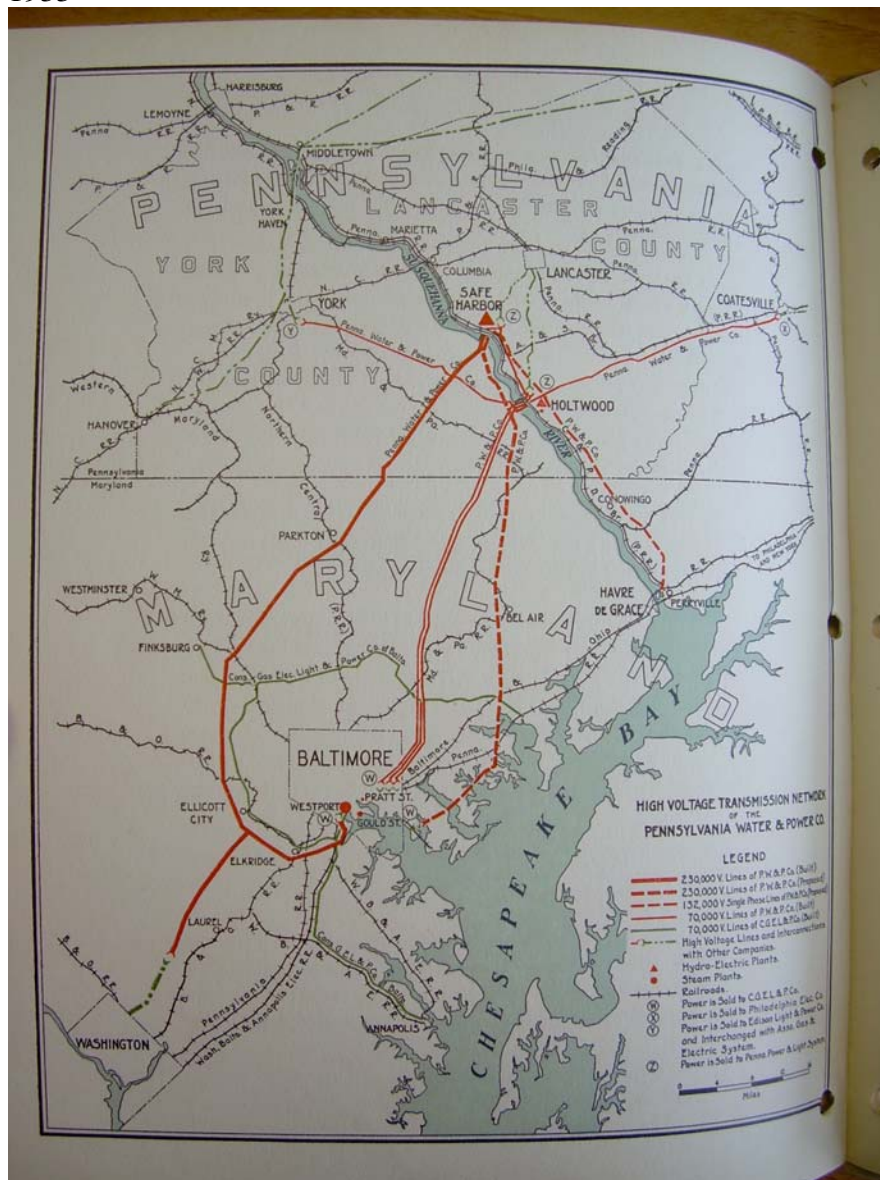
¹⁰² "A Wholesaler of Electric Power" *Barron's* April 20, 1931.

¹⁰³ Pennsylvania Water & Power Company, *1936 Annual Report*, Pennsylvania Water & Power Company, *1939 Annual Report*.

¹⁰⁴ In 1923, Lancaster used over 100 million kwh, while Consolidated sold 85 million kwh to its consumers in 1912. Lancaster data from memo: "Minutes of Meeting at Lancaster, Friday, October 13, 1924" Nov 3, 1924. Hagely PWP Collection Accession 1552, Box 149, Folder 24. Consolidated data from Consolidated, *1923 Year Book*, 8.

kwh in 1938.¹⁰⁵ Once businesses, shopkeepers, and homeowners were able to acquire cheap electricity, they increased their consumption exponentially.

Map 5.2: The Pennsylvania Water & Power Company Transmission Wire Network, 1933¹⁰⁶



¹⁰⁵ Industrial survey of Baltimore and Consolidated Gas Electric Light and Power Company of Baltimore, *Second Industrial Survey of Baltimore. A Quarter Century of Progress in the City of Industrial Advantages, 1914-1939*, 17.

¹⁰⁶ Image courtesy of Hagley Museum & Library, Wilmington, DE. Pennsylvania Water & Power Company, 1933 *Annual Report*.

Power Grids in the Mid-Atlantic, 1900-1930

When the Pennsylvania Water & Power Company constructed its transmission wires from the Holtwood Dam to Baltimore in 1910, they fit the pattern of electricity transport in the mid-Atlantic and nation as a whole. At this date, long-distance transmission wires were used almost exclusively to link hydroelectric dams with urban markets. For example, transmission wires connected hydroelectric dams at Niagara Falls, the Adirondack Mountains, and the Delaware River with the region's cities. Unlike the organic economy, where people and industries moved to sites of water power, transmission wires enabled hydroelectricity to be diverted to urban industries.

A survey of the electricity transmission wires built in the mid-Atlantic before 1910 demonstrates the direct connections between hydroelectric power and long-distance transmission. According to a comprehensive survey undertaken by the trade journal *Electrical World*, there were 24 transmission wires operating in New York and Pennsylvania at 44,000 volts or above. Over two-thirds of these were located in western New York around the Niagara Falls power developments. Three took hydroelectric power from the Adirondack Mountains to Utica and its suburbs. Four more wires were built in central Pennsylvania from a small hydroelectric station at Warrior Ridge.¹⁰⁷ Thus, all the long-distance wires built during this decade in the mid-Atlantic were affiliated with hydroelectric developments. The mid-Atlantic was not unique in this regard. A survey in 1914 documented 55 transmission wires operating at or above

¹⁰⁷ The Niagara, Lockport, and Ontario Power Company operated 17 power lines at 66,000 volts spanning 475 miles from Niagara Falls to cities like Buffalo and Rochester. The Utica Gas & Electric Company and Adirondack Power & Light Company operated the lines from the Adirondack Mountains. The Penn Central Light and Power Company erected 135 miles of transmission wires between Warrior Ridge, Altoona, Lewistown, and Mount Union between 1906 and 1910. "Engineering Details of the Transmission Lines in the United States at and above 44,000 Volts," *Electrical World* 85, no. 1 (1925).

70,000 volts across the world (including the lines between the Holtwood Dam and Baltimore). All but six were connected to hydroelectric plants.¹⁰⁸

Most of the nation's electricity did not come from water power, however. Steam-fired turbines burning coal produced most of the electricity. For example, in 1912, 73 percent of the nation's capacity at central power stations was powered by steam and 27 percent was powered by water. The mid-Atlantic relied even more heavily on steam—at a ratio of approximately 79 percent steam to 21 percent hydroelectric.¹⁰⁹ The use of coal-fired steam power in the mid-Atlantic was largely a product of earlier energy landscapes. Coal canals, which were later eclipsed by railroads, made anthracite and bituminous coal cheap, abundant, and reliable in the mid-Atlantic thereby giving steam-generated electricity a cost-advantage in the region. The transport of steam-generated electricity, therefore, had a different logic. Coal was shipped hundreds of miles by railroads to urban generating stations, burned to produce electricity, and then transported short distances to consumers.

Between 1910 and 1930, the use of long-distance transmission wires in the mid-Atlantic became much more common and was no longer exclusively linked to hydroelectric dams. Three trends were particularly important for stimulating these developments. The first factor was the increasing separation between site of production

¹⁰⁸ "Transmission Systems of the World Operating at and above 70,000 Volts, Ranked According to Operating Voltage."

¹⁰⁹ The nation had 8,116,086 hp of installed steam capacity and 2,942,388 of hydroelectricity in 1912. Pennsylvania and New York had 614,396 hp out of a total capacity of more than 2,800,000 hp in the same year. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations and Street and Electric Railways, 1912* (Washington: Government Printing Office, 1915), 28, 29, 36. This ratio held relatively steady during this time period. In 1927, hydroelectric turbines represented 20 percent of the region's installed capacity (1,708,051 hp out of a total of 8,614,712). United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1927* (Washington: Government Printing Office, 1930), 41.

and site of consumption. At the beginning of the twentieth century, many industrial enterprises generated their own power, meaning that electricity did not even need to travel beyond the walls of the factory.¹¹⁰ Throughout the nineteenth century, industries had been accustomed to supplying their energy needs, whether by installing a water wheel or operating a steam engine. When a company chose to replace their existing power source with electricity, they typically purchased their own dynamos and operated them internally. By the 1910s and 1920s, most factory operators decided it was cheaper and more efficient to purchase electricity from centralized utility stations.¹¹¹ This transition increased the amount of electricity that needed to be transmitted, at the very least from the central station to the factory.

The gradual expansion of the area served by utility companies also drove the expansion of the transmission wire network. In 1910, Consolidated of Baltimore served an area of 88 square miles with 16,605 customers. By 1925 they had expanded to serve 158,608 customers over a 600 square mile area.¹¹² Public Service Electric & Gas, which controlled the large majority of electric supply in New Jersey, had only 47 miles of transmission wires in 1903. By 1913, the company created a more integrated network by building 576 miles of transmission wires, mostly operating at 6,600 and 13,200 volts.¹¹³

¹¹⁰ In 1899, over 60 percent of electricity was produced by non-utility companies. Street railways accounted for approximately two-thirds of this and manufacturing establishments one-third. See Table 6.1 and Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, Appendix II: 388, 423.

¹¹¹ The industries that continued to produce their own electricity were predominantly large, energy-intensive, and continually operated industries such as steel mills. Central stations produced less than 40 percent of the nation's electric supply in 1899 but increased their share to 60 percent in 1918 and 77 percent by 1929. Ibid.

¹¹² Consolidated Gas Electric Light and Power Company of Baltimore, *Year Book* (Baltimore: Consolidated Gas Electric Light and Power Co., 1925), 24.

¹¹³ Data from James Coniff and Richard Coniff, *The Energy People: A History of PSE&G* (Newark, NJ: Public Service Electric and Gas Company, 1978), 123-31, 273-84.

The expansion of utility networks both geographically and in terms of increased numbers of consumers required steady additions to the transmission systems.

However, the creation of regional utility conglomerates was the most important reason for the expansion of long-distance transmission wires. Between 1900 and 1930, and most acutely between 1915 and 1925, the majority of electric utility companies in the mid-Atlantic were consolidated into regional monopolies owned by large holding companies. For example, in 1924, over 70 percent of privately-owned electric generating capacity was under the control of holding companies.¹¹⁴ The mid-Atlantic was no exception—in 1922, it was estimated that 98 percent of Pennsylvania's power came from prime movers owned by holding companies.¹¹⁵

There is a subtle distinction between holding companies and regional conglomerates. Holding companies were financial schemes that brought several utilities under the overall management of a single organization. The holding company provided several benefits to the individual companies including access to financing, technical expertise, and management experience. Regional conglomerates were collections of utilities operating collectively in the same region. Sometimes holding companies also created conglomerates of regional utilities. For example, the United Gas Improvement Company was a holding company that purchased control of the Philadelphia Electric Company in 1928. Because United Gas Improvement Company also controlled the Counties Gas & Electric Company, the Philadelphia Suburban Gas & Electric Company

¹¹⁴ Federal Trade Commission, "The Electric Power Industry: Control of Power Companies," (Washington: Government Printing Office, 1927), 40.

¹¹⁵ Pennsylvania. Giant Power Survey Board., Gifford Pinchot, and Janet B. Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania* (Harrisburg, PA: Printed by the Telegraph Printing Company, 1925), 48. In all likelihood this number is too high, as it includes the Aldred companies as a holding company, for example. However, it is true that the large majority of the utilities were brought into conglomerates in Pennsylvania during this time.

as well as sixteen other smaller units operating in the Philadelphia area, it was able to bring the entire region under the management of a single organization. However, holding companies did not only acquire utilities in the same region. For example, United Gas Improvement also owned utilities in Iowa, Nebraska, New Jersey, Virginia, and Florida.¹¹⁶ The desirability of the proliferation of holding companies was a hotly debated topic at the time, as will be discussed later in this section, and led to the development of alternative political visions for the organization of the electric industry.¹¹⁷

Regional conglomerates were often formed by holding companies, but sometimes they emerged independently. For example, the Aldred companies (Consolidated, Pennsylvania Water & Power, and Safe Harbor Water & Power) operated as a regional conglomerate, but were not part of a holding company scheme. The Philadelphia Electric Company, while owned by a holding company, was the center of a regional conglomerate in the mid-Atlantic. Regional conglomerates offered an additional benefit beyond financial, technical and management assistance: improved performance through system interconnection over high-voltage wires. As regards the creation of transmission wires, the important development was the formation of regional conglomerates, a process that was connected with, but not identical to, the holding company movement.¹¹⁸

¹¹⁶ "Interconnection Brings Mergers," *Electrical World* 91, no. 1 (1928): 45; Wainwright, *History of the Philadelphia Electric Company, 1881-1961*.

¹¹⁷ The report of the Federal Trade Commission in 1927 on the ownership patterns of the electric power industry was one of the most significant investigations: Federal Trade Commission, "The Electric Power Industry: Control of Power Companies."

¹¹⁸ While holding companies were not necessary for creating interconnections, they greatly facilitated this trend. It is comparable to the discussion of the relationships between the Pennsylvania Water & Power Company and Consolidated. It is conceivable that independent corporate entities could have formed a long-term power-sharing agreement, but it would be a highly risky and unlikely proposition without the security of common ownership. The holding companies greased the wheels of interconnection in the mid-Atlantic in the same way that Aldred's ownership of both companies facilitated their long-term relationship.

Integrating the different systems of a regional conglomerate using transmission wires offered at least three technical benefits: improving the reliability of service, achieving a better load balance, and consolidating generation at new and more efficient stations. First, interconnection improved reliability because it allowed a utility to draw power from other locations if a generator malfunctioned. This was especially important due to the high cost and difficulty of storing electricity.¹¹⁹ Therefore, if one generator failed or needed repairs, supplementary power could be sent over transmission wires.

Second, transmission wires helped regional conglomerates improve their load factor—the ratio of the utility’s overall generating capacity to its average use.¹²⁰ A utility had to invest enough capital to handle the peak load (the biggest draw on the system at any given time) but was rarely able to utilize its entire capacity for more than a brief period of time. Utility companies sought to improve their load factor by encouraging diverse uses of electricity that would consume power at different times of day. Combining the loads of several different utilities offered another strategy. If hypothetical utility companies A, B, and C each had a peak load of 25,000 kilowatts, then they would need to invest in at least this much generating capacity. However, if the peak loads of the systems occurred at different times, the maximum demand of all three utilities might only be 60,000 kw. By building interconnecting wires and sharing power, the three utilities

¹¹⁹ The Electric Storage Battery Company in Philadelphia sold battery systems capable of storing 1,500 kw of electricity by 1904. However, this required a large room containing several hundred batteries, each of which weighed several tons. American Institute of Electrical Engineers, *Philadelphia Electrical Handbook; a Sketch of the City and Some of Its Great Enterprises for the Information of Visitors from Abroad Attending the International Electrical Congress, St. Louis, Missouri, September, 1904* (Philadelphia: Published under the auspices of the American Institute of Electrical Engineers, 1904).

¹²⁰ For example, if a company used 100 kw of power 12 hours a day, the utility serving this company would have a load factor of 50 percent, since the 100 kw of generating capacity would sit idle for the other 12 hours a day.

could save money by avoiding an additional 20 percent investment in generating equipment.

The third opportunity for saving money came from installing large and modern generating equipment. Between 1900 and 1930 the size and efficiency of electricity generators increased dramatically. A 5,000 kw generator in 1905 was considered large, as was a 12,000 kw generator in 1912. By 1929, there were generators with capacities exceeding 200,000 kw.¹²¹ Larger and more modern generators produced more electricity using less fuel and at a cheaper cost. Returning to our hypothetical utilities in the previous paragraph, suppose that each anticipated a load growth of 10,000 kw over the next five years. It would be far more cost-efficient to build a single 30,000 kw generating station rather than three separate 10,000 kw installations.

The benefits of interconnection can be seen in the actions of the Metropolitan Edison Company in 1923. The company already controlled utilities in several cities in eastern Pennsylvania (Easton, Reading, York) and New Jersey (Dover). In 1923, the company extended its territory into central and southern Pennsylvania by purchasing utilities in York Haven, York, and Hanover. Second, it expanded its network of transmission lines by building a 110,00-volt line connecting Reading and Easton. Third, it constructed a 30,000 kw steam plant at Middletown along the Susquehanna River near Harrisburg and began work on a 200,000 kw plant along the Delaware River by Easton.¹²² Each of these moves (buying up companies, building transmission wires, constructing large generating stations) was related, as it only made sense to concentrate

¹²¹ Richard F. Hirsh, *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System* (Cambridge, Mass.: MIT Press, 1999), 46.

¹²² Metropolitan Edison, *Annual Report*, 1923. Accessed at Hagley PWP Collection, Accession 1552, Box 151, Folder 12 "Metropolitan Edison Co. (York Haven) 1916-1923—General."

production in large plants if one had the transmission wires to move it and the broad customer base to balance the load and absorb the full output of a large new generating station.

Of course, regional utility conglomerates had non-technical benefits for utility companies as well. Most importantly, they led to a significant reduction in regional competition. Even though most utility companies operated with monopoly privileges in a given geographic area, they were still required to justify their rates to various regulatory commissions. By lowering competition, regional conglomerates could charge higher prices and experience less pressure from regulatory agencies.

By 1930 the various utilities in eastern Pennsylvania had been gathered into a small number of regional conglomerates. These oligopolistic enterprises included Metropolitan Edison, Philadelphia Electric Company, Pennsylvania Power & Light (which controlled utilities throughout the anthracite region including service in Mauch Chunk, the Panther Valley, Mahoney, and Wilkes-Barre), New Jersey Public Service Electric & Gas (which controlled most of New Jersey), and the Aldred companies (Consolidated, Pennsylvania Water & Power, Safe Harbor Water & Power).

The economic benefits of integrating networks through load sharing and building efficient generating stations could only be achieved with a mechanism for transmitting the power between the utilities. High-voltage long-distance wires filled this need. Between 1910 and 1919, 28 new lines were built. Several of the hydroelectric companies, including Pennsylvania Water & Power, Niagara, Lockport, and Ontario Power, Utica Gas & Electric, and Adirondack Power & Light extended their transmission networks, together building ten additional wires operating at 66,000 volts spanning about

280 miles. This decade also witnessed the first development of transmission wires designed for networks of steam plants. In Pittsburgh, the Duquesne Light & Power Company constructed a one hundred mile network of ten 66,000-volt wires between its coal-fired plants and the West Penn Electric Company built two additional wires of the same voltage with a length of over 60 miles. The Penn Central Light & Power Company extended its network with an additional 100 miles of 45,000-volt wires through five separate lines, although it appears that no new hydroelectric stations were involved.¹²³

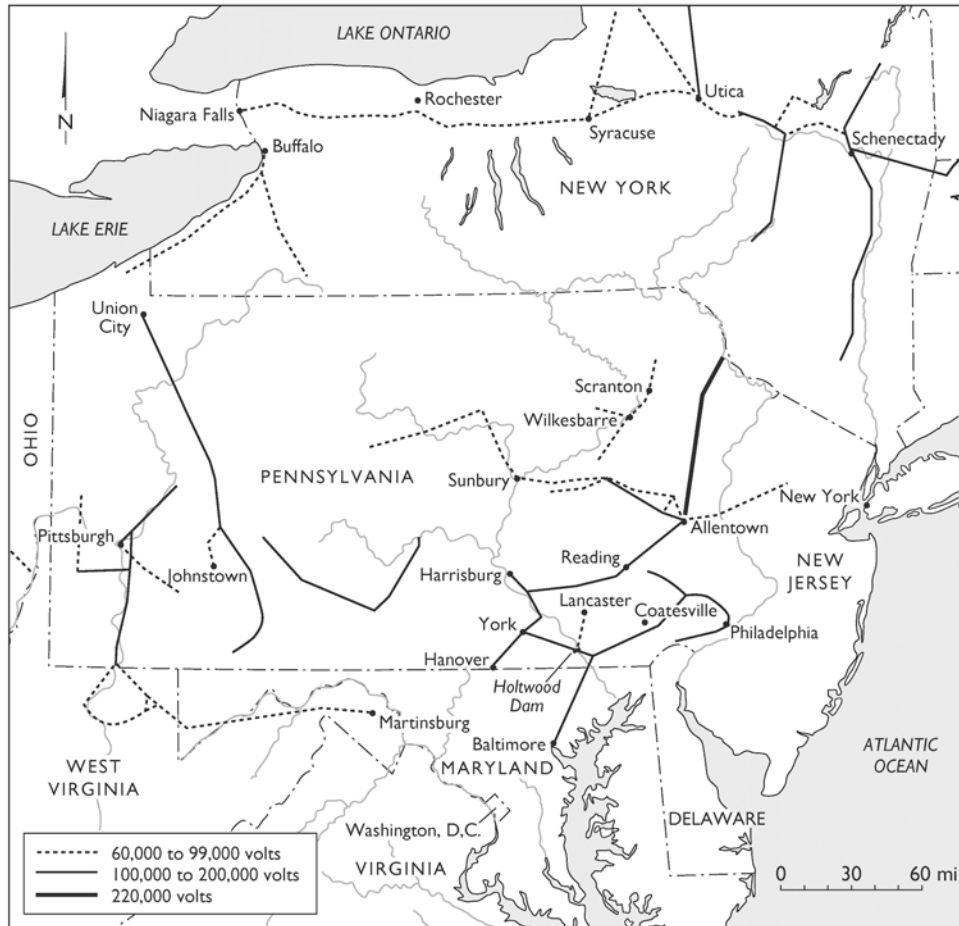
Between 1920 and 1924, there was a dramatic increase in the pace of transmission wire construction that helped create a broader grid of lines in the region. There had been about 1,200 miles of high-voltage transmission lines built between 1900 and 1919 in the mid-Atlantic. In the five years between 1920 and 1924, utilities built an additional 2,200 miles of transmission wires, including the region's first 110,000-volt wires. These wires were largely the result of the interconnections between regional utility conglomerates. Many of the companies that had built wires in the preceding decades expanded their networks by acquiring new utilities and markets. For example, companies like Niagara, Lockport, and Ontario Light & Power, Duquesne Light & Power, and Penn Central Light & Power expanded their networks. In addition, new conglomerates such as Metropolitan Edison (seven wires of at least 66,000 volts spanning 200 miles) and Penn Public Service Corporation (four wires traveling 225 miles at 110,000 volts) entered the field. By the end of 1924, there were a total of 130 high-voltage transmission wires stretching nearly 3,500 miles across Pennsylvania and New York.¹²⁴ The region now had a transmission

¹²³ "Engineering Details of the Transmission Lines in the United States at and above 44,000 Volts."

¹²⁴ Ibid.

grid network connecting its hydroelectric and steam plants with urban consumption centers.

Map 5.2: Map of Transmission Lines 60,000 Volts and Higher, 1925



The Politics of Integration

By 1920, it was widely recognized that utility companies could produce electricity more cheaply when they combined diverse loads and shared generating capacity via transmission networks. However, there was significant debate about what form this “sharing” or “collaboration” would take. Despite the benefits of lower costs, many worried that the emergence of holding companies and consolidation within the industry

would lead to monopoly conditions. Without competition the savings in generation costs might go to financiers, not customers. In addition, anti-monopoly advocates had recently had their greatest victory, with the court-ordered breakup of the Standard Oil Trust in 1911, thereby encouraging those opposing the rise of holding companies. Throughout the 1920s, and continuing into the 1930s with Roosevelt's New Deal programs, politicians, businessmen, and citizens debated how regional networks should be formed, who should own them, how they should be operated, and most importantly, who would benefit the most from them.

Many of the differing perspectives can be understood through the history of Superpower, Giant Power, and the PNJ Interconnection. Superpower and Giant Power were government-initiated proposals that sought to create regional networks across the eastern seaboard and Pennsylvania, respectively. Neither proposal was implemented, but they provide a useful perspective on debates at the time. Drawing on some of the ideas of Superpower, the PNJ Interconnection was a set of electricity transmission wires and operating arrangements between three large regional conglomerates in the mid-Atlantic. Understanding why Superpower and Giant Power failed while the PNJ Interconnection succeeded gives us insight into the power dynamics of regional transmission networks.

The ideas for the Superpower proposal emerged during the energy shortages of World War I.¹²⁵ Due to a combination of increasing coal prices, material shortages, and high demand from war-related industries, most utilities in the mid-Atlantic and across the nation had difficulty supplying enough electricity. These energy shortages disrupted

¹²⁵ The history of Superpower can be found in several sources, including: William S. et al. Murray, "A Superpower System for the Region between Boston and Washington," (Washington: Government Printing Office, 1921); Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970".

manufacturing for the war effort and led to unreliable electric service in all sectors.

Utilities found it difficult to increase their output due to long lead-times for installing new capacity, shortages of materials, and high labor costs. Several observers from the industry noted that electricity shortages often occurred in one location while surrounding utilities had extra power. The total supply of energy was not the critical problem—it was a transport issue. If there was a mechanism to share power between utilities, they reasoned, many of the shortages could be avoided.

This observation did not lead to the creation of regional connections during the war, but it did inspire the development of a Superpower proposal shortly afterwards. William S. Murray, a consulting engineer to railroad companies, began conceptualizing a plan to interconnect the electrical grids in the American northeast. He envisioned creating a Superpower zone between Washington D.C. and Boston that extended from the coast about 150 miles inland. He began talking with other engineers and politicians about building high-voltage transmission lines between utilities, concentrating production at large plants, and electrifying the trunk-line railroads. He hoped that the electrification of the railroads would reduce the burden of carrying coal, thereby opening freight space for higher-value industrial goods and conserving the supply of coal.

In 1920, Murray obtained financial support from the Secretary of the Interior to investigate his ideas further under the auspices of a Superpower survey. He gathered a team of utility executives, electrical engineers, and financial analysts together and formed an Advisory Board that sought to determine how such a system could be implemented.¹²⁶

¹²⁶ Several of the engineers and executives associated with hydroelectric projects on the Susquehanna participated as consultants to the Superpower project, including Boyd Ehle, Cary T. Hutchinson, and J.A. Walls.

The board quickly agreed on the engineering aspects of the proposal. The economic benefits of regional integration were clear and the technology of transmission wires was well understood. However, the members could not reach an agreement on issues of financing, ownership, and regulation. The utilities refused to accept a plan that allowed the Federal government to purchase Superpower properties after 50 years, while the government was unlikely to grant eminent domain privileges and other incentives for the project without additional regulation.

In the end, the Superpower Advisory Committee agreed to present the technical aspects of the proposal without addressing the legal, political, and financial aspects. The report was printed on June 30, 1921 and received favorable newspaper coverage.¹²⁷ However, little direct action came of the proposal since it did not provide a mechanism for its implementation. While various groups continued to discuss ideas of Superpower over the next several years, it was not implemented according to Murray's vision.

Superpower was not the only government proposal for transmission networks on the eastern seaboard. Under the leadership of the engineer and former utility regulator Morris Cooke and Governor Gifford Pinchot, Pennsylvania developed an alternative vision of electrification. Pinchot had become famous for his conservation work as head of the Forestry Service and had been elected on a reform platform. Once in office, he worked with Cooke to develop a new proposal for electrification in Pennsylvania. According to Cooke and Pinchot, the existing networks in Pennsylvania were being run for the benefit of the corporations, not the people. They believed that consumers paid too much for electricity that was being generated in old and inefficient plants, that rural areas

¹²⁷ Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970", 47.

had too little access to electricity, and that the Superpower scheme was designed to maximize profit, not benefits for common people.

Cooke had been an early advocate of the Superpower system and a friend of Murray's, but had distanced himself when Murray publicly critiqued the Ontario Hydro-Electric Commission in 1922.¹²⁸ The Ontario system was a very well regarded public power project and Cooke thought Murray's critique painted an unfair picture of government's role in the electric industry. In 1923, he convinced Pinchot to develop an alternative plan for Pennsylvania that would use the power of government to create an electric distribution system that would benefit individual consumers, not large utility companies. They successfully petitioned the state for authorization of a "Giant Power" survey in 1923 and began work.

In 1925, Cooke and Pinchot presented an ambitious proposal to the Pennsylvania legislature. Although the proposal shared many of the technical features of the Superpower plan—high-voltage transmission wires, large and efficient generating stations, railroad electrification—it also included major initiatives for rural electrification, rate reductions for residential consumers, and expanded government oversight. The center of the system was a series of large "mine-mouth" generating plants located in the heart of western Pennsylvania's bituminous coalfields. Smaller and less efficient stations in the east would be phased out and the electricity would be shipped across the state over a series of 220,000-volt transmission lines 300 miles in length. The coal would be pre-treated to recover its bi-products, thereby further lowering the cost of electric production. While some questioned particular aspects of the technical elements of the plan, such as

¹²⁸ Ibid., 50.

whether there was sufficient cooling water at mine-mouths and how power plants on the east coast would be phased out, it was the other provisions of Giant Power that elicited the strongest responses.¹²⁹

The report's calls for shifts in distribution, ownership, and oversight were controversial: Pinchot and Cooke were recommending a significant shift in the relationships between the government and industry. Pinchot and Cooke argued this was necessary to obtain desirable social outcomes. They claimed the difference between Superpower and Giant Power was like that between a tame and wild elephant: "One is the friend and fellow worker of man—the other, at large and uncontrolled, may be a dangerous enemy. The place for the public is on the neck of the elephant, guiding its movements, not on the ground helpless under its knees."¹³⁰ The men painted the consolidation of the electric industry as a serious threat: "under the control of a single monster corporation...If uncontrolled, it will be a plague without previous example."¹³¹ Only with a more active government role, Pinchot and Cooke argued, could society increase rural electrification, lower the electric rates paid by domestic consumers, and protect itself from the dangers of corporations.

As these sentiments make clear, Giant Power was not simply a proposal to increase the reliability of electricity. For Cooke and Pinchot, along with many other contemporaries, electricity was more than an energy source: it was essential to improving the human condition. Ronald Tobey's aptly titled book, *Technology as Freedom*,

¹²⁹ Some of the technical differences of opinion, including whether there was sufficient cooling water, processes for recovering coal bi-products, and markets for these products, are discussed in *Electrical World*: "A Disappointing Report," *Electrical World* 85, no. 9 (1925).

¹³⁰ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, vii. The quotation is as it appears in the text, despite the appearance of a typographical error.

¹³¹ *Ibid.*, ix, xi.

captures the widespread belief in the 1920s and 1930s that electrification would lead to numerous social benefits.¹³² For instance, Pinchot argued that electrification provided the opportunity to return to a pastoral ideal of living in the countryside: “Steam brought about the centralization of industry, a decline in country life, the decay of many small communities, and the weakening of family ties. Giant Power may bring about the decentralization of industry, the restoration of country life, and the upbuilding of the small communities and of the family.”¹³³ Giant Power was a social movement as well as a technical proposal.

While there was widespread sentiment that many of the aims of Giant Power were socially desirable, the proposed restructuring of the utility industry galvanized its opponents. A mostly factual recounting of the proposal in *Electrical World* was titled “Pinchot Takes a Radical Stand.”¹³⁴ William Murray called the ideas “communistic” and “rotten at the core.”¹³⁵ In addition, the Giant Power report was vague about how its goals would be achieved. It called for the creation of a Giant Power Board that would be responsible for implementing the broad goals. In January and February of 1926, a Joint Committee between the House and Senate of the Pennsylvania Legislature met to discuss the proposal. Opponents of the bill brought in industry experts to argue that the plan was not realistic and would damage Pennsylvania’s power system. Ultimately, the Joint

¹³² Ronald C. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home* (Berkeley: University of California Press, 1996).

¹³³ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, xii.

¹³⁴ “Pinchot Takes a Radical Stand,” *Electrical World* 85, no. 8 (1925).

¹³⁵ William S. Murray, “To the Editor of Electrical World,” *Electrical World* 85, no. 10 (1925).

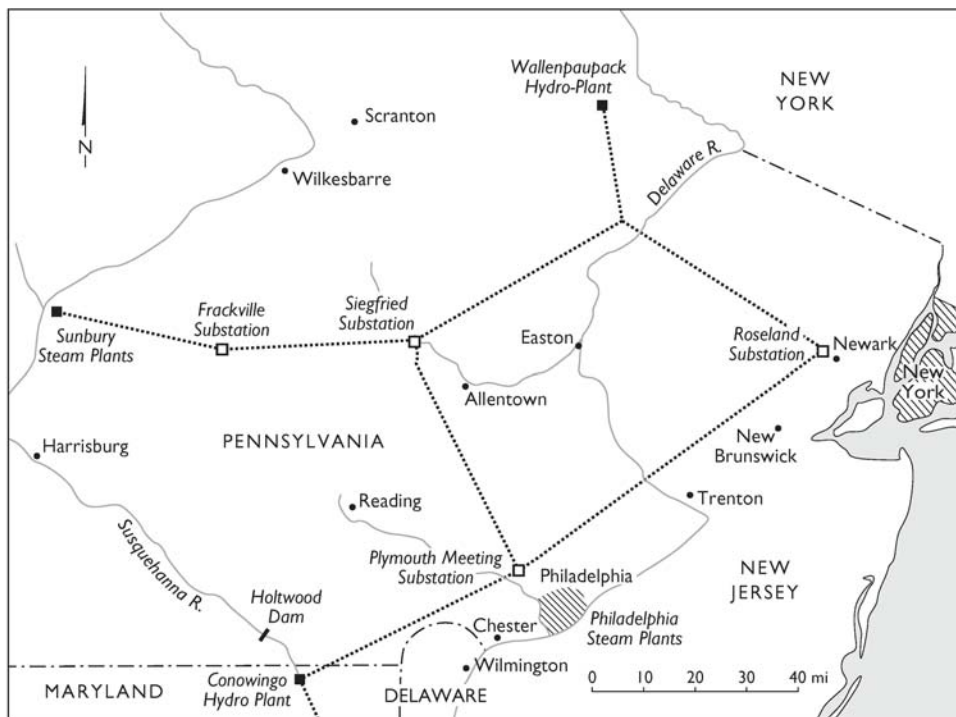
Committee agreed with the opponents and voted against the proposal on February 8, 1926.¹³⁶ It does not appear that the bill was ever re-introduced.

While neither Superpower nor Giant Power was implemented in a way that their founders intended, the general discussion of interconnection did lead to new energy transmission patterns. However, it would be developed by utilities, not government. In 1927, Pennsylvania Power & Light, the Philadelphia Electric Company, and Public Service Electric & Gas came together to create the PNJ Interconnection. The three parties agreed to construct a 210-mile 220,000-volt set of transmission wires that would connect each company's systems at four locations: Bushkill, PA, Siegfried, PA, Plymouth Meeting, PA, and Roseland, NJ. The transmission network would allow each company to share electricity efficiently so as to minimize overall production costs.¹³⁷

¹³⁶ Thomas Parke Hughes, "Technology and Public Policy: The Failure of Giant Power," *Proceedings of the Institute of Electrical and Electronics Engineers* 64 (1976): 1369-70.

¹³⁷ Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*, 321.

Map 5.3: PNJ Interconnection, 1928



The logic of the PNJ Interconnection was essentially the same as sharing electricity within the several branches of a regional conglomerate. By having access to power from other suppliers, each company lowered its overall capital requirements for electricity generation, obtained additional reliability, and balanced its load versus that of other suppliers. As Bayla Singer noted in her study of the PNJ Interconnection, it was a conservative strategy that fit the utilities' current working model.¹³⁸ The PNJ Interconnection provided a technical and administrative structure that encouraged the utilities to share power whenever it was profitable to do so without disrupting the existing patterns of the industry.

Even though there were technical similarities between Superpower, Giant Power, and the PNJ Interconnection—all involved creating high-voltage long-distance

¹³⁸ Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970", 106.

transmission lines to connect the region's generating stations—their histories reveal much broader debates about the politics of such a system. In the end, the fact that the PNJ Interconnection was designed by and paid for by utility companies meant that certain political visions were excluded. The final agreement did not call for centralization of production, electrification of railroads, conservation of coal, rural electrification, or reduced rates to consumers. It simply provided a mechanism for the utility companies to reduce costs. The strength of the holding companies would not be challenged, and their utility companies would continue to increase their profits.

However, the ambitions in Superpower and Giant Power did not die entirely. Some of them were integrated into New Deal reforms in the 1930s that achieved greater government regulation and rural electrification. In 1935, the Public Utility Holding Act forced several holding companies to dissolve, including eventually forcing Aldred to resign his role as director of Pennsylvania Water & Power and Consolidated. The Rural Electrification Act did more to bring electricity to farms than any efforts undertaken by the utilities.¹³⁹ Taken collectively, these various visions of electrification demonstrate that differences in how transport networks are constructed can lead to very different social outcomes.

Conclusion

The Holtwood Dam and its transmission wires created new relationships between mid-Atlantic residents and their environment. Before the erection of the dam, the raging powers of the Susquehanna River were considered too remote and variable to be of much

¹³⁹ For information on the influence of New Deal programs on electrification, see: Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*.

use as an energy source. Transforming the river's power into hydroelectricity that could be shipped cheaply and abundantly to urban locations changed this logic—it created a new energy landscape. Similar to the development of canals and pipelines, this energy landscape took concentrated energy from rural regions and transported it to the region's urban centers. Moreover, by providing mid-Atlantic residents with ever-increasing quantities of energy, the dam and its wires contributed to the deepening of the mineral economy.

In 1910, the dam and its transmission wires were pioneering electrical developments in the region. The dam was the most extensive in America and the wires were among the longest in the region. Over the next twenty years, other utilities in the region began to follow the Pennsylvania Water & Power Company's example. Utility companies formed regional conglomerates and used transmission wires to link their various generating stations, similar to the way the Holtwood Dam's wires exchanged power between the Susquehanna River and Baltimore's steam-fired plants.

Collectively, the mid-Atlantic's transmission wire network directed large amounts of energy to the region's industrial cities. There was nothing natural or inevitable about this. As revealed by the histories of Superpower, Giant Power, and the PNJ Interconnection, citizens, businessmen, and politicians debated where transmission wires should be built, how they should be operated, and who they should benefit. Of course, the region's history influenced the outcome of these debates. Earlier energy landscapes of coal and oil had encouraged the rise of industrial cities by making fossil fuel energy cheap and abundant in urban cores. Once electricity was added to the region's energy mix, it followed many of the patterns established by coal and oil.

Electricity transmission wires pushed the region further into the mineral economy. Wires enabled electricity to be generated at one location and then shipped to another. They made electricity cheaper in the regions they served by lowering the capital construction costs of utility companies. Wires increased the reliability of electrical service by providing linkages between various generating plants in case one of them failed. Cheap and reliable electricity, in turn, provided people with new opportunities to use energy in homes, factories, and for transport. How, when, and where mid-Atlantic residents used this energy and how it accelerated the transition to a mineral economy is the subject of the next chapter.

Chapter 6: Electricity Consumption and the Mineral Economy, 1900-1930

The widespread introduction of electricity has been one of the most important transformations of the twentieth century. By providing a flexible energy source that can be used in homes, shops, and factories, electricity has altered many of the ways Americans live, work, and play. A typical American today uses electric power dozens of times daily, in alarm clocks, coffee makers, computers, elevators, televisions, vending machines, and more. The extent of our current dependence on electricity is clearly revealed on those rare occasions when the power goes out. For example, the widespread electrical blackouts hitting the Northeast in August of 2003 disrupted life-support systems at hospitals, shut down many transportation systems, and crippled communication networks. It even forced wealthy tourists visiting New York City to sleep in hotel lobbies when the electric locks on their doors could not be opened.

These patterns have their roots in electrical practices developed between 1900 and 1930. During these years, mid-Atlantic residents created new uses for electricity that changed their world. Electric lighting created new visual landscapes for cities and homes; electric streetcars made suburban living practical; electric motors in factories facilitated the rise of new forms of work organization such as assembly lines; and the use of domestic appliances initiated the use of fossil fuels for mechanical energy in the home. Overall, these new consumption patterns helped solidify the development of a mineral economy in the mid-Atlantic. By 1930, the mid-Atlantic was an urban and industrialized

society using coal, oil, and electricity to surpass the limits to growth characteristic of an organic economy.

Electricity had many features in common with coal and oil but also introduced new twists to the energy practices of the mid-Atlantic. Coal, oil, and electricity were similar in that all could be used to provide heat, light, and power. However, electricity was unique because of the flexible ways it could provide these services. In particular, deriving power from coal and oil usually required large and cumbersome steam or internal combustion engines. These worked well to provide power in mines, forges, railroads, and automobiles, but did not have much potential to be used on a small scale (consider the difficulty of operating an alarm clock with a coal-fired steam engine!). Electricity could be used in devices of any size, allowing the development of small (and cheap) electrical appliances like radios and irons as well as massive dynamos capable of powering entire factories. As a result, electricity created new possibilities for the consumption of mineral energy sources in the mid-Atlantic's homes, factories, and cities.

This chapter connects the development of the transmission wire networks studied in the previous chapter to their broader social impacts. Webs of wires made new electricity consumption patterns possible for many, although not all, residents of the mid-Atlantic. However, they did not, by themselves, determine what shape these changes would take. This chapter studies how electric energy was used in the mid-Atlantic and how these patterns varied both within the region and in comparison with other parts of the United States. In particular, I emphasize the four major uses of electricity during this time period—lighting, street railways, industrial power, and domestic appliances—and their effects on the mineral economy. In the conclusions, I examine who gained and lost

the most and how electrification perpetuated an ongoing dependence on mineral energy sources.

Putting the Energy Landscape to Work

Wires linked consumers with the generating stations that transformed falling water or fossil fuel into flows of electricity. Although it rarely mattered to consumers whether their power came from water or fossil fuels, the source of the electricity influenced its transport patterns. Hydroelectric power usually traveled long distances between rivers and cities. Coal-fired power plants, on the other hand, relied on the long-distance transport of fossil fuel energy to urban generating stations and then short transmission wires to deliver the power to consumers. Regardless of how it was produced, most electricity in the mid-Atlantic between 1900 and 1930 was consumed in the same type of place: the region's urban centers.

The creation of the Holtwood Dam on the Susquehanna River reflected the logic of large-scale hydroelectric developments in the mid-Atlantic. Transmission wires shipped most of the power from these dams away from rivers to distant cities. The Holtwood and Safe Harbor dams on the Susquehanna River supplied electricity to Baltimore as well as Lancaster, York, and Coatesville. The power of the Conowingo Dam, completed in 1926 on the Susquehanna River, was mainly transmitted to Philadelphia. The Wallenpaupack Dam, on a tributary of the Delaware River, transported its power to Allentown, Williamsport, and Scranton. Dams in the Adirondack Mountains shipped their current to Albany, Utica, Schenectady, and Syracuse.

The hydroelectric facilities at Niagara Falls were a slight exception to this pattern. When the first turbines were installed in 1895, transmission wire technology was still in its infancy. Therefore, several metallurgical and electrochemical factories established themselves near Niagara Falls, creating a small industrial center. Over time, engineers constructed a series of transmission wires that carried much of the electricity to Buffalo, Rochester, and Syracuse, but the Niagara area remained an important site of production.¹ The example of Niagara Falls, therefore, is more reminiscent of the organic economy and the mills at Lowell, Massachusetts than the Holtwood Dam.

Electricity created by burning fossil fuels followed a different transport logic. Most of the region's electricity was generated using coal.² In general, coal-fired generating stations were located in the urban areas where their power was consumed. These stations, in turn, relied on previously built energy landscapes. Most importantly, they depended on the cheap and abundant transport of coal to cities. By 1900, the transition from canals to railroads for the shipment of coal was practically complete. In fact, coal constituted the greatest volume of freight for the nation's railroads. In 1922, coal represented a third of Pennsylvania's railroad traffic—3 billion ton miles.³ Therefore, electricity generated from coal utilized two energy landscapes: railroads to ship coal hundreds of miles to urban generating stations, and wires to ship the electricity the remaining few miles to customers.

¹ Hughes, *Networks of Power: Electrification in Western Society, 1880-1930*, 264-65.

² Small amounts of electricity were created using natural gas and petroleum, but this was a minor part of the trade. While 1,751,731 tons of anthracite and 8,716,744 tons of bituminous were used, there were only 298,696 barrels of fuel oil (comparable to about 40,000 tons of coal) and 5,872,307 thousand cubic feet of natural gas (comparable to approximately 215,000 tons of coal) used to generate electricity. United States Bureau of the Census, *Census of Electrical Industries: Street Railways, 1927* (Washington, DC: Government Printing Office, 1930), 45.

³ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 54.

Whether it was produced at rivers in rural areas or in urban generating stations, electricity was mainly consumed in the mid-Atlantic's cities between 1900 and 1930. This pattern also reflected the operations of previous energy landscapes—canals, railroads, and pipelines had enabled people and industries to concentrate in urban locations over the previous decades. Urbanites had greater needs for mineral-based energy sources and greater wealth with which to purchase them. Moreover, the density of population and industries made it cheaper and easier for utilities to serve urban customers because it meant less wire, poles, and transformers had to be installed.

The energy landscape of electricity transmission and consumption was similar to coal canals and oil pipelines, but it was not identical. First, electricity served a much broader range of cities. Coal canals and oil pipelines funneled the largest amounts of energy to a few urban locations, primarily New York City and Philadelphia. While the region's major cities continued to absorb the lion's share of electrical production, most of the mid-Atlantic's cities had established electric service by the early years of the twentieth century. For example, there were more than thirty cities in Pennsylvania with electric streetcar service by 1912, including smaller locations such as Bloomsburg (7,413 residents in 1910), Chambersburg (11,800), Dubois (12,623), Lock Haven (7,772), McKeesport (42,694), and New Castle (36,280).⁴ By 1922, 785 of 1,212 incorporated towns in Philadelphia had access to some level of electricity, serving about three-quarters of the population.⁵

⁴ United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations and Street and Electric Railways, 1912*, 218. Population numbers for 1910 from Andriot, *Population Abstract of the United States*, 697-701.

⁵ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 55.

Second, the energy landscapes of electricity transformed the geography of cities by spurring the growth of suburbs. As will be discussed further in the next section, electric streetcars played a critical role in encouraging suburban living. By making it practical and cheap for workers to live more than a few miles away from their sites of employment, streetcars facilitated the geographic expansion of the city into its hinterlands. With improved urban and suburban transport, many cities expanded from a dense cluster of buildings whose borders were only a few miles apart into sprawling collections of homes and factories spread out in a rough circle with a diameter of more than twenty miles.

By contrast, there was very little electrification outside of cities and their suburbs by 1930. For those living in the countryside, rural electrification was a rarity before 1930. Only 2 percent of farms in the nation had electric service in 1910 and 10 percent by 1930 even though home electrification rates were 16 percent in 1912 and 68 percent in 1930.⁶ The mid-Atlantic had slightly higher rural electrification rates than other American regions, but the percentage of farms served was still quite low. In 1925, 178,666 of Pennsylvania's 202,250 farms lacked electric service (12,452 were supplied by utilities, and 11,132 operated their own generators either independently or in collectives).⁷

The pathways of transmission wires often determined which rural areas had access to electricity. Due to the lack of population or industrial concentration outside of

⁶ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 288, 395, footnote 50; Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970", 231-4.

⁷ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 37.

cities, it was rarely cost-efficient for utilities to build wires to rural areas. However, some sites got access to electricity simply by being located along the pathway of a transmission wire between two cities or a hydroelectric dam and a city. In such cases, it was possible to build a transformer station that would make power available. However, there was no guarantee that this would actually happen. For example, the transmission wires between the Holtwood dam and Baltimore did not provide service to any in-between points.

The low rates of rural electrification in the mid-Atlantic and America in general were partly a result of geography and dispersed settlements, but they were also a product of social choices. Several other nations including Holland (nearly universal), Germany (90 percent), and New Zealand (67 percent) had managed to achieve much more impressive rates of electrification by 1930.⁸ Furthermore, once the United States passed the Rural Electrification Act in 1935 subsidizing the financing of rural transmission lines, the rates increased sharply, showing that policy decisions had tangible impacts on development patterns.⁹ Rural electrification owed more to government efforts than the invisible hand of the market.

Consuming Electricity, Shaping the Mineral Economy

Electricity is distinctive as an energy source because of its variety of uses and the scales at which it can be applied. Similar to coal and oil, electricity could be used to generate heat, light, and power. What made electricity different was the fact that it could

⁸ Rural Electrification Administration and David Cushman Coyle, *Electric Power on the Farm: The Story of Electricity, Its Usefulness on Farms, and the Movement to Electrify Rural America* (Washington: Government Printing Office, 1936), 72-4.

⁹ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, chapter 7.

provide variable levels of power. Coal and oil used in steam and internal combustion engines produced large quantities of power that were only suitable for industrial or transport purposes. Electricity, on the other hand, could safely and cheaply supply energy to motors small enough to be used in people's daily lives and large enough for industrial operations. It was particularly through the spread of small-scale energy applications that electricity helped mid-Atlantic residents extend the practices of the mineral economy to new domains. Four applications of electricity were particularly significant between 1900 and 1930: lighting, street railways, industrial power, and domestic appliances. Each of these practices contributed to the mineral economy in distinct ways.

Overview of Electrical Consumption

Table 6.1 provides an overview of all electrical production and consumption in the United States between 1902 and 1927 to contextualize the importance of various applications. Although the data are taken only from Census publications, they have been compared with other sources of statistics including publications of industry trade groups (National Electric Light Association, Edison Electric Institute, *Electrical World*) and other government organizations (United States Geological Survey) and found to be similar (most values were within a couple percentage points).¹⁰ Table 6.1 reveals a number of broad trends over time, such as the relative decrease of street railways as

¹⁰ National Electric Light Association, *The Electric Light and Power Industry in the United States* (New York: National Electric Light Association, 1928); Edison Electric Institute, *The Electric Light and Power Industry in 1932* (New York: Edison Electric Institute, 1933); United States Geological Survey, *Monthly and Annual Production of Electricity for Public Use in the United States in 1930* (Washington: Department of the Interior, 1931); "Statistical Summary of Progress in the Electrical Industry," *Electrical World* 91, no. 1 (1928).

consumers of electricity, the significant increase of industrial enterprises, and the slow rise of residential consumption. I have yet to find any source of comparable data for the mid-Atlantic as a whole, but where possible I use particular bits of data to indicate when the region followed and deviated from national patterns.

Table 6.1: U.S. Electricity Consumption By Sector, 1902-1927, in Millions of KWH¹¹

Year	Total KWH (millions)	Residential	Industrial	Street railways	Commercial	Other (losses, imports, miscellaneous)
1927	102,404	7,676 (7%)	54,407 (53%)	9,390 (9%)	10,766 (11%)	20,156 (20%)
1922	61,816	3,916 (6%)	25,727 (42%)	12,405 (20%)	7,180 (12%)	12,588 (20%)
1917	43,863	1,731 (4%)	16,510 (38%)	12,188 (28%)	5,213 (12%)	8,221 (19%)
1912	25,000	910 (4%)	5,198 (21%)	9,020 (36%)	4,076 (16%)	5,796 (23%)
1907	14,262	~428 (3%)	3,680 (26%)	6,009 (42%)	~1,293 (9%)	~2,852 (20%)
1902	6,029	~121 (2%)	1,201 (20%)	2,651 (44%)	~851 (14%)	~1,206 (20%)

Lighting

Improved lighting was the first commercially successful implementation of electricity. Beginning with Thomas Edison's 1882 Pearl Street Station providing illumination for Wall Street, lighting has been the most long-standing and widespread use of electricity. Whether in cities, homes, stores, or factories, electric light was a highly desired service.

¹¹ The statistics in this table are derived from several Census publications, most notably United States Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970* (Washington: Government Printing Office, 1975), 820, 828. and United States Bureau of the Census, *Census of Electrical Industries: Street Railways 1902-1927* (Washington: Government Printing Office, 1905-1930). Total KWH, Residential (1912-1927), and Commercial (1912-1927) is from Census, *Historical Statistics to 1970*, p. 820, 828. Street Railways is from Census, *Census of Electrical Industries: Street Railways, 1902-1927*. Industrial is derived from taking the production as given in Census, *Historical Statistics to 1970*, p. 820 and subtracting the production of street railways companies as given in Census, *Census of Electrical Industries: Street Railways, 1902-1927*. Other (1912-1927) is determined by subtracting the other categories from the total. The values for 1902 and 1907 for Residential, Commercial, and Other are estimated. I assume that Residential was 3% in 1907 and 2% in 1902 and that Other was 20% in these years. Dividing this percentage by total production gives these values, while the remaining production is allocated to the Commercial sector for these years.

Municipalities were the largest early adopters of electricity. Many mid-Atlantic cities had been trying to upgrade their street illumination for several decades and were often pioneers in establishing gas light and electric arc lamp systems in the nineteenth century. During the 1880s when many cities adopted electric lighting, there were few private utilities in operation. As a result, many cities established their own municipal generating stations that lit city streets and buildings and sold their excess capacity to homes and stores. These installations were usually justified on the grounds that better street lighting would lead to safer streets and a more beautiful town. However, the decision to invest in street lighting was not solely rational. Street lighting was a symbol of modernity and towns competed with one another to have the best displays. Civic pride was at least as important of a motivating factor as safer streets in the early adoption of street lighting.¹²

If electric lighting was important to the status of municipalities, this was an even greater incentive for commercial establishments. Shops in downtown regions, particularly department stores, used electric lighting in extravagant ways as part of their marketing efforts. The historian David Nye has described this as the Great White Way, noting that the ways commercial enterprises used lighting far exceeded functional requirements: “electrification was a form of conspicuous consumption that said, ‘We are progressive and growing.’”¹³ Electric lighting encouraged the practice of shopping at night and provided a catalyst to the growing advertising industry. Because of the cultural associations between electric lighting displays and modernity between 1900 and 1930, commercial enterprises invested heavily in lighting technology.

¹² Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 18.

¹³ *Ibid.*, 54.

In the home, electricity quickly replaced kerosene and gas as the main source of lighting whenever it was available and people could afford it. The carbon-filament light bulb was as bright as gaslight without the downside of noxious fumes, dirty fixtures, fire risk, and over-heated rooms. When the tungsten-filament bulb became common around the turn of the century, it offered an unparalleled level of brightness. As Wolfgang Schivelbusch noted, “[t]he enthusiasm with which electric light was hailed in the late nineteenth century is in many respects reminiscent of the reaction evoked by gas lighting seventy years earlier. In their time, both innovations were regarded as the most modern, the brightest, cleanest and most economical form of lighting.”¹⁴ During the first few decades of the twentieth century, the majority of home electric consumption came from lights. The pace and adoption of electric lighting in the home was highly influenced by wealth and location. Wealthy homes in cities began to install electric lighting in the 1880s, while it took until after World War I for the majority of American homes to have access to electricity. For those living in the country, electric lighting was still rare by 1930 regardless of income level.¹⁵

Electric lighting was a boon to several industries, as well. As opposed to manufactured gas, electricity produced superior light without several of the downsides of gas. For example, electric lights did not leak gas which could lead to head aches, were less prone to starting fires (insurers often reduced rates when gas lights were replaced), gave off much less heat keeping factories more comfortable in the summer, and were more flexible as they could be moved around a room. For jobs requiring precision work

¹⁴ Wolfgang Schivelbusch, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century* (Berkeley: University of California Press, 1988), 69.

¹⁵ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 28.

(such as many aspects of textile or craft work), flexible light that could be adjusted to the job made a significant difference in the quality of work.¹⁶

Determining exactly how much electricity was used for lighting in cities, homes, stores, and industries is difficult. To get a sense of the total amount of electricity in lighting, we can return to Table 6.1 and look at the various user groups. For residential consumers, lighting was the main use of electricity besides domestic appliances, which only began to occupy a larger percentage of overall consumption by the end of the period (as will be discussed later). The same was true of commercial enterprises, which adopted light eagerly at the beginning and then began to use electricity for other purposes in the stores such as fans and elevators towards 1930. Lighting also made up a surprisingly large amount of industry's electric consumption, particularly in the early years when non-power uses prevailed (see Table 6.3). In addition, as street railway companies also sold extra electricity to consumers, it is likely that a small percentage of their consumption went towards lighting. Putting all this together, with rough estimates for the percentage of use in the various sectors, results in Table 6.2.

Table 6.2 involves several estimates, so its data should be read carefully.¹⁷ In general, it reveals that the overall amount of electricity consumed for lighting represented a significant percentage of early consumption but that its relative importance faded over

¹⁶ Ibid., 193.

¹⁷ The data is corroborated by other sources, giving some assurance that it is reasonably accurate. For example, the 1917 and 1922 *Census of Electrical Industries* indicates that central stations sold 5,112,412,219 and 9,777,114,508 kwh of electricity for lighting purposes, respectively. They made this calculation assuming that all commercial and all residential consumption was for lighting while excluding the sales of street railway companies and the lighting used in industry. If some residential and commercial consumption is excluded while industrial and street railway consumption is added, then one gets quite similar results. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1917* (Washington: Government Printing Office, 1920), 87; United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1922*, 83.

time. Even though the consumption of electricity for lighting increased roughly ten-fold between 1902 and 1927, it failed to keep pace with growth in other sectors. The percentage of electricity used for lighting showed a steady decrease over the period, from roughly over a quarter of all consumption to less than a sixth. It does not appear that lighting patterns were significantly different in the mid-Atlantic region.

Table 6.2: Electricity Used in Lighting, United States, 1902-1927¹⁸

Year	Total KWH (millions)	Residential	Industrial	Street railways	Commercial	KWH used for lighting
1927	102,404	3,838 (50%)	4,897 (9%)	188 (2%)	7,536 (70%)	16,459 (16%)
1922	61,816	2,350 (60%)	2,315 (9%)	744 (6%)	5,385 (75%)	10,794 (17%)
1917	43,863	1,212 (70%)	2,311 (14%)	122 (10%)	4,170(80%)	7,815 (18%)
1912	25,000	683 (75%)	1,092 (21%)	902 (10%)	3,465 (85%)	6,142 (25%)
1907	14,262	342 (80%)	957 (26%)	601 (10%)	1,164 (90%)	3,064 (21%)
1902	6,029	109 (90%)	504 (42%)	265 (10%)	766 (90%)	1,644 (27%)

Table 6.3: Percentage of Electricity Used By Industry For Lighting, 1902-1927¹⁹

Year	Power	Materials conversion	Support services	% of support services used for light (estimate)	% of industrial consumption used for light (Column 4 X Column 5)
1929	70%	17%	13	65%	8.45
1920	70.9%	15.2%	13.9%	70%	9.7
1913	59.2%	13.7%	27.1%	75%	20.3
1899	30%	10%	60%	80%	48

The use of electricity for lighting contributed to the development of the mineral economy in several ways. First, it provided an essential financial basis for the expansion of the electrical industry. Utilities typically charged much higher rates to residential and

¹⁸ The percentage in each category refers to the percentage of total consumption in that sector estimated to be for illumination. The number of KWH is derived from multiplying the percentage by total consumption in that sector as presented in Table 6.1. The estimate of residential consumption is based on a declining percentage as domestic appliances were introduced (see the section on domestic appliances). The estimate for commercial consumption also assumes a decreasing percentage as other electric devices for stores became available. The industrial value is derived from Table 6.3, and then extrapolated on a linear basis to fit the dates. The street railway total is based on an estimate of the total light and power business of street railways, which decreased over this period.

¹⁹ Sam H. Schurr et al., eds., *Electricity in the American Economy: Agent of Technological Progress*, Contributions in Economics and Economic History (New York: Greenwood Press, 1990), 295. Note: support services includes lighting and information processing. As there was not widespread electronic use of information processing equipment, it is likely that the large majority of this consumption was used for lighting. As more alternative devices were developed during this period, I have lowered the percentage accordingly.

commercial customers who used electricity for lighting than they did to industrial consumers using the current for power.²⁰ For example, in 1902, it was reported that lighting represented over 80 percent of the revenues of central generating stations across the nation.²¹ Utilities in the mid-Atlantic were responsible for more than a third of this output and sales.²² Lighting, therefore, subsidized the growth of the electrical industry in its earlier years while new applications were developed.

As a financial stimulant to the industry, electric lighting was very similar to kerosene for the oil industry. Kerosene was the primary use of the mid-Atlantic's oil production during the nineteenth century, generating rich financial rewards for refiners. However, kerosene consumption could not keep pace with the use of oil for power and transportation in the first decades of the twentieth century. While kerosene growth nearly doubled from 1900 to 1930, the use of gasoline and fuel oil grew sixty and fifty fold, respectively. To a lesser extent, lighting played a similar role in the electrical industry. It was a large part of early sales, but faded in importance over time as other applications increased their relative importance much more quickly.

Electric lighting was also similar to kerosene in that it pushed people further away from cultural practices characteristic of the organic economy. Artificial lighting allowed

²⁰ Industries were able to negotiate much lower rates (often twenty cents on the dollar in relation to residential and commercial customers) for two reasons. First, they typically used much larger amounts of electricity. Second, industrial enterprises had leverage over utilities because they had the financial and technical resources to operate their own electrical generators if they were unhappy with utility rates.

²¹ Total revenues for electricity by central stations in 1902 were \$84,186,605. \$25,481,045 came from arc lighting, \$44,657,102 from incandescent lighting, and \$14,048,458 from other sources. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1902* (Washington: Government Printing Office, 1905), 38.

²² Plants in New York, New Jersey, and Pennsylvania generated 40% of the total electrical output, 35% of total electrical sales, and about 35% of the revenues from lighting. Mid-Atlantic revenues for all electricity sales in 1902 were \$29,410,354, consisting of \$9,525,124 from arc lighting, \$14,517,410 from incandescent lighting, and \$5,367,720 from other sources. Total output was 1,021,603,500 kwh. Ibid.

people to read and work at any time of night and during the long winter evenings.

Just as kerosene helped to separate people from the experience of living according to the seasons, electric lighting continued these trends. Moreover, electricity made it even easier for mid-Atlantic residents to use artificial light. While kerosene lights required a household to purchase kerosene at the store, fill lamps, and tend wicks, electric lights could be operated with the flick of a switch.

Street Railways

Street railways were one of the most important uses of electricity in the decades surrounding the turn of the twentieth century. Electric streetcars provided a new form of urban transport that could effectively move people around cities in ways that transcended the capabilities of previous systems. In particular, street railways made the development of suburban living patterns both practical and desirable. Taking advantage of cheap and rapid transport to and from work sites in the urban core, millions of mid-Atlantic residents chose to buy homes in the suburbs. The establishment of suburbs, in turn, had critical consequences for the development of a society dependent on mineral energy sources. Once people established homes several miles away from work locations, they required regular transport options that exceeded the capacity of organic energy sources. Streetcars provided these transport services for the first decades of the twentieth century. In the 1920s and 1930s, personal automobiles began to replace streetcars, a development that further entrenched the dependence of mid-Atlantic residents on mineral energy sources.

In the late 1880s, when electric streetcars began to be introduced, cities already had access to organic (horses pulling omnibuses) and mineral (steam railroads) transport systems. However, each of these systems had limitations. Horse-drawn omnibuses were slow, expensive, and polluting. Moreover, they traveled little faster than a person walking. If we take an hour's commute as a maximum distance people could live from their work locations, horse-drawn omnibuses and walking required people to live within three or four miles of stores and employment opportunities.²³ Steam railroads were not much more useful. People resisted their introduction onto city streets because they were noisy, polluting, and dangerous. Moreover, steam railroads were most effective for long-distance transport, not the continual starting and stopping every couple blocks needed for urban transport. Commuter railroad systems typically had stops only every quarter mile and served less than ten percent of local traffic in the late nineteenth century.²⁴

Electric streetcars, by contrast, could travel more quickly along city streets and carry a greater number of passengers than horse-drawn omnibuses.²⁵ Their electric motors were quiet and could be started and stopped quickly. Street railways averaging eight or nine miles per hour made it practical for people to live as far away as six miles from work locations and be able to commute within an hour's time. Express routes with fewer stops expanded the range of service, thereby allowing people to live even further

²³ Five miles per hour was the maximum average speed for horse-drawn omnibuses. Riders also had to allocate a few minutes to walk to an omnibus stop, wait for a ride, and then walk to their final destination. Charles W. Cheape, *Moving the Masses: Urban Public Transit in New York, Boston, and Philadelphia, 1880-1912* (Cambridge, MA: Harvard University Press, 1980), 4; Sam Bass Warner, *Streetcar Suburbs: The Process of Growth in Boston, 1870-1900* (Cambridge: Harvard University Press, 1962), 16.

²⁴ Cheape, *Moving the Masses: Urban Public Transit in New York, Boston, and Philadelphia, 1880-1912*, 2-5.

²⁵ Warner estimates that streetcars could consistently travel twice as fast and carry three times as many passengers. Warner, *Streetcar Suburbs: The Process of Growth in Boston, 1870-1900*, 28.

away. The result of streetcars was to make it practical for urban cores to increase from a diameter of roughly five miles to twenty to twenty-five miles.²⁶

The ability to move passengers efficiently through cities was particularly important for Philadelphia and New York, whose populations in 1890 were 1,046,964 and 1,515,301, respectively.²⁷ By 1912, New York City led the nation in total passengers with more than a billion paid riders per year using electrified transport covering more than 700 miles of track. Philadelphia streetcars provided nearly half a billion rides annually using 650 miles of track.²⁸ However, streetcars were not exclusive to New York City or Philadelphia. By 1912, there were more than 70 street railway systems operating throughout Pennsylvania, New York, and New Jersey.²⁹

Electric railways did not only operate within city boundaries. While most streetcars ran within a five to ten mile radius of city centers, their services were supplemented by the development of interurbans, electrified trains connecting nearby cities. While the network of steam railroads developed over the nineteenth century made travel between cities possible, their rates, routes, and schedules tended to favor freight over passengers. Interurbans focused on passenger traffic along with light and high-value freight such as mail. The development of a reliable interurban network made it much easier for people to travel between cities and for those in the country to visit a city for the

²⁶ Cheape, *Moving the Masses: Urban Public Transit in New York, Boston, and Philadelphia, 1880-1912*, 2.

²⁷ In fact, the congestion in New York City had led to urban rapid transit systems before the dawn of the electrical age: steam railroads running along elevated tracks beginning in 1871. Given that the railroad could halve travel time, many of its public costs—noise and pollution—were accepted. However, electric streetcars and subways in New York soon eclipsed the use of steam railroads. *Ibid.*, 31.

²⁸ New York City had 1,108,237,017 riders in 1912 and Philadelphia had 456,926,814. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations and Street and Electric Railways, 1912*, 215.

²⁹ *Ibid.*, 218.

day. Interurbans also extended suburbanization: for example, interurbans extended suburbanization from New York City all the way to Nassau County.

As a corollary to creating residential living patterns in the suburbs, streetcars encouraged the creation of centralized commercial and industrial districts. Especially in conjunction with interurbans that could bring rural residents into the cities, streetcars gave a great boost to the development of a commercial downtown where several shops could be concentrated. Large downtown stores, and department stores in particular, benefited from this concentration at the expense of country stores. Similarly, several industries took advantage of the fact that streetcars allowed their workers to travel to sites further from downtown. For some industries, this allowed them to obtain cheaper land. For others, it allowed them to move nearer to transport facilities or raw materials. In this way, street railways and interurbans brought people closer together and pushed them further apart. The development of electrified transport allowed rural and suburban residents to enter cities to shop and work at sites in urban cores, but they also led to a geographic dispersion of both industrial sites and population.³⁰

Finally, streetcar companies were also important because they supplied electricity to consumers in their service areas. Because their demand for electricity around the turn of the century was too great for most utilities to handle, most streetcar companies operated their own generating stations. When they had excess electricity, particularly in the evening hours when fewer trolleys were in operation, they sold this power to consumers along the routes of the streetcars where their wires were already established. As a result, living along the path of a streetcar did not only mean that a family had access

³⁰ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, chapter 3.

to transportation, it also meant that they were much more likely to have electrical service. This was especially the case along the paths of the interurbans. For rural residents, one of the only opportunities to purchase electrical current was to tap the wires of a nearby interurban.

By the turn of the century, street railway companies used nearly half of all the electricity consumed across the nation. As seen in Table 6.4, the total electrical consumption of street railway companies continued to increase up through 1922, although not nearly as quickly as other sectors. As a result, by 1927, street railway companies had more than tripled their electrical demand but had seen the percentage of overall consumption decrease from 44 percent to 9 percent of the total. By the end of the 1920s, the era of the street railway companies was coming to an end. A combination of general economic decline that commenced with the Great Depression and competition from motor buses and automobiles led to a dramatic decrease in street railway operations.

With only about 20 percent of the nation's population, the mid-Atlantic was the nation's leading region in streetcar development, transporting over 35 percent of the passengers and using more than 30 percent of the total electricity (see Table 6.5). New York City operated the nation's largest streetcar network while Philadelphia's was the third most extensive behind Chicago by 1902.³¹ The fact that the mid-Atlantic was more urban than other regions contributed to this heavier use. In 1925, there were 122 electric street railway companies in 55 of Pennsylvania's 67 counties.³²

³¹ United States Bureau of the Census, *Census of Electrical Industries: Street Railways* (Washington: Government Printing Office, 1905), 24.

³² Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 57-58.

Table 6.4: Street Railway Electrical Consumption, U.S., 1902-1927³³

Year	Total electrical production (kwh)	Total street railway (kwh)	% electricity used by street railways	Total passengers carried
1927	102,404,000,000	9,389,597,006	9%	14,901,435,276
1922	61,816,000,000	12,405,052,635	20%	15,331,399,851
1917	43,863,000,000	12,187,850,831	28%	14,506,914,573
1912	25,000,000,000	9,020,017,789	36%	12,135,341,716
1907	14,262,000,000	6,009,130,100	42%	9,533,080,766
1902	6,029,000,000	2,651,484,397	44%	5,836,615,296

Table 6.5: Street Railway Electrical Consumption, Mid-Atlantic, 1902-1927³⁴

Year	Total kwh street railways (US)	Total kwh street railways (mid-Atlantic)	% kwh mid-Atlantic	Passengers (mid-Atlantic)	% passengers (mid-Atlantic)
1927	9,389,597,006	3,596,286,186	38%	5,707,319,536	38%
1922	12,405,052,635	3,582,760,388	29%	5,466,020,707	36%
1917	12,187,850,831	3,305,150,097	27%	5,027,469,984	35%
1912	9,020,017,789	2,717,965,936	30%	4,125,221,246	34%
1907	6,009,130,100	2,015,156,289	34%	3,512,933,679	37%
1902	2,651,484,397	992,237,709	37%	2,331,783,405	40%

The decrease in street railways at the end of this period should not distract us from the significant social consequences of these technologies. The development of street railway companies had major effects on the shape of mid-Atlantic cities and the daily lives of their residents. Streetcars significantly expanded the physical parameters of the city, altering where people lived, worked, and shopped. In addition, streetcar companies often brought electricity to new parts of cities and competed with utilities to provide electrical service, particularly in the early years of the twentieth century.

Streetcars also contributed to the development of the mineral economy in the mid-Atlantic. First, streetcars required large amounts of mineral energy for power. In 1925, Pennsylvania's street railway companies used 921,062,435 kwh of power—the energy equivalent of 519,698 tons of coal.³⁵ Given that New York used nearly twice as much energy transporting passengers and New Jersey consumed an additional several hundred

³³ Total electrical production is taken from Table 6.1. Electricity produced, electricity purchased, and total passengers carried is from United States Bureau of the Census, *Census of Electrical Industries: Street Railways 1902-1927*.

³⁴ Data from Table 6.5 and Ibid.

³⁵ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 57-58.

thousand kilowatt-hours, the mid-Atlantic likely burned more than a million and a half tons of coal per year simply to move its urban populations between home, work, and stores.³⁶

Using mineral energy for everyday travel was not simply significant for its total levels of fossil fuel consumption. This new behavior was a mineral-based response to an unintended consequence of the mineral economy. The transport of coal, oil, and electricity enabled the concentration of people and industries in urban cores. As populations expanded to hundreds of thousands and then millions of residents, this urban growth created new problems; namely, how to get people to and from the places they would live and work. The solution to the problem was characteristic of the mineral economy: use fossil fuel energy to power streetcars. In other words, fossil fuels were used to solve a problem created by fossil fuels in the first place.

Industrial Power

Industries consumed the greatest amounts of electricity between 1900 and 1930, increasing their use at a dramatic rate. At the turn of the century, only about 20 percent of all electrical production was used for industrial purposes, and much of this was used for lighting (Tables 6.1 and 6.3). By 1927, however, industrial consumers absorbed over half of the nation's electricity, and had increased their use of kilowatt-hours nearly fifty-

³⁶ New York consistently had approximately twice the passenger riders of Pennsylvania from 1902 to 1912 while New Jersey had about a quarter of the traffic of Pennsylvania. For example, in 1912, New York consumed 1,701,299,210 kwh, Pennsylvania 799,997,221 kwh, and New Jersey 216,669,505 kwh. In 1902, New York had about 1,150,000,000 riders, Pennsylvania approximately 625,000,000, and New Jersey roughly 195,000,000 riders. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations and Street and Electric Railways, 1912*, 193, 280.

fold in just twenty-five years.³⁷ Whereas electric motors accounted for less than 5 percent of the total horsepower used in industry in 1899, more than 82 percent of industrial motors were driven by electricity by 1929.³⁸

As an industrial power source, electricity replaced existing technologies and created new possibilities. In this capacity, electricity in industry had parallels to its use in street railways. Mineral-based transport systems already existed but streetcars enabled safe and efficient travel along city streets. Similarly, electric lighting and power in factories both supplemented existing practices and opened the door for new ones.

The first industrial uses of electricity simply replaced existing systems. Electric lights provided artificial illumination that was brighter, safer, and more flexible than gas lights. A company could replace its steam engines or water wheels with an electric dynamo as well. With water wheels and steam engines, factories typically used a line-drive system, a series of shafts and leather belts that ran along the ceiling, to transfer the power to each worker's station. By replacing a water wheel or steam engine with an electric dynamo, organizations could obtain greater control over the output of power, start and stop the line drives more easily, and increase the efficiency of their power production. Because factories were accustomed to supplying their own power with water and coal, many of them operated their own electrical equipment during the first years of the twentieth century. It was only as central utilities became larger and more reliable that factories began to purchase electricity.³⁹

³⁷ See Table 6.1.

³⁸ Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 187.

³⁹ Warren D. Devine Jr., "Electrified Mechanical Drive: The Historical Power Distribution Revolution," in *Electricity in the American Economy*, ed. Sam H. Schurr, et al. (New York: Greenwood Press, 1990).

Over time, factory operators began to discover that electricity had unique features that could be used to change industrial practices. A key insight was that wires could replace the line-drive systems of leather belts and shafts with a unit-drive system that placed a motor at each work station. With the line-drive system, all of a company's work operations had to be laid out in linear paths connected to the overhead belts. Moreover, the central steam engine or water wheel had to be in use at all times. With electric power and a unit-drive system, each work station could be powered by its own motor, which could be turned on and off as needed. Moreover, wires could transfer power to any site in the factory, freeing operators to organize production according to the flow of parts, not just the delivery of power. In other words, the distinctive features of electric power were a crucial precondition for the widespread adoption of the assembly line and the implementation of Tayloristic schemes.⁴⁰

Electric power was not adopted by all industries at the same rate. New enterprises, like automobile manufacturers and companies producing electrical equipment, were typically rapid adopters of electrical power. Industries including baking, ready-made clothing, printing, and machine tooling quickly converted to electrical power as their main source of supply as well. Mature industries that had large investments in previous power systems—particularly flour milling, sugar processing and refining, and the lumber industry—were often slower to transition because of their sunk costs. However, even organizations like manufactured gas companies and coke

⁴⁰ Ibid.

manufacturers with significant investments in coal technology were using large amounts of electrical power by 1930.⁴¹

Electricity could be used for more than simply providing power to machinery. For example, precision machinery such as electrolytic ovens with thermostats made it much easier to maintain a furnace at the right temperature for forging metal. Electricity could also be used to create new materials. For example, aluminum was considered a more valuable metal than gold or silver in the mid-nineteenth century before it was discovered that it could be generated in significant quantities through electrolysis. As discussed in the previous chapter, the Pennsylvania Water & Power Company created a subsidiary to produce ferro-silicon, an important material for steel-making, as a way to profit from unused electrical current. The amount of industrial electricity devoted to materials conversion increased from 10 percent in 1900 to 17 percent by 1929 (Table 6.3).

The relative safety and flexibility of electrical power encouraged its use in mining operations. Underground coal mines, despite being the basis of the mid-Atlantic's mineral economy, were dangerous places to use coal and oil because they could lead to explosions of accumulated gas. Electricity, by contrast, offered a safer way to deliver

⁴¹ The 1930 Census collected data on the horsepower of prime movers used in various industries in 1929. They distinguished between electrical (driven by purchased electricity versus electricity generated in-house) and power driven by steam engines, internal combustion engines, and water wheels. Companies making motor-vehicle bodies and motor-vehicle parts had 816,430 horsepower of motors driven by electricity versus 112,508 driven by other power sources. Manufactures of electrical machinery had 844,070 hp driven by electricity versus 277,954 hp non-electrical. Bakers and bread makers (347,296 electrical vs. 38,522 non-electrical), men's and women's clothing (68,206 vs. 9,961), printing and publishing (535,551 vs. 31,800), and machine tools (61,822 vs. 3,206) disproportionately used electricity. Flour and grain (366,835 electrical vs. 308,022 non-electrical), beet and cane sugar (194,830 vs. 287,991), and lumber (884,533 vs. 1,704,262) adopted electricity slower than most other industries. Manufactured gas companies used 222,222 hp of electrical energy in addition to 365,412 hp from other sources and coke manufactures 366,561 and 281,686 hp of electrical and non-electrical energy, respectively. United States Bureau of the Census, *Abstract of the Fifteenth Census of the United States: 1930* (Washington: Government Printing Office, 1933), 824-27.

power to miners. Operators of mining enterprises used electricity to replace steam for the pumps that drew water out of the mines, supplement human muscles and dynamite with electric drills, and substitute electric motors for the mule teams that had traditionally hauled coal to the surface.⁴² Mining enterprises used approximately 15 percent of the electricity consumed by industries during this period.⁴³ Given the mid-Atlantic's prominent coal and oil industries, this energy was disproportionately consumed in the region.

The use of electricity in industry was particularly important in the mid-Atlantic. This is not surprising, given the fact that the mid-Atlantic's advantages in obtaining coal and oil over the preceding century had established the region as the nation's primary manufacturing area. With 20 percent of the nation's population, mid-Atlantic industries consumed at least 30 percent of the total electricity used by industries nationwide in 1927.⁴⁴ In fact, the ratio may be significantly higher. For the nation as a whole, approximately 60 percent of industries purchased their energy from utility companies and 40 percent of them operated their own dynamos in 1925.⁴⁵ According to the Giant Power

⁴² By 1904, the Baldwin Locomotive Works in Philadelphia had already introduced several models of electrified locomotives to haul coal out of mines. American Institute of Electrical Engineers, *Philadelphia Electrical Handbook; a Sketch of the City and Some of Its Great Enterprises for the Information of Visitors from Abroad Attending the International Electrical Congress, St. Louis, Missouri, September, 1904*, 67-70; Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 204.

⁴³ The percentages were 18% in 1912, 13% in 1917, 15% in 1922, and 14% in 1927. United States Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970*, 828.

⁴⁴ 33,471,610,198 of the kwh sold by utilities in the nation were purchased by industrial consumers (53% of total sales of 63,612,481,088 kwh). 10,138,146,714 kwh (30%) were consumed in the mid-Atlantic. In addition, mid-Atlantic industries likely consumed at least an additional 5,500,000,000 kwh of electricity (the mid-Atlantic produced 28,616,322,115 kwh from all sources. Subtracting the 19,281,644,834 kwh and 3,596,286,168 kwh produced by utilities and street railways, respectively, leaves an additional 5,738,391,113 kwh produced by independent establishments, almost all of which were industries). United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1927*, 41, 47, 51, 78.

⁴⁵ In 1925, the National Electric Light Association estimated that 60.7% of electricity used by industries was purchased from utilities. Schurr et al give a similar estimate, noting that in 1926 62% of industries

Survey, in 1922 only one-third of the electric power used in industry and mines in Pennsylvania was purchased from utilities.⁴⁶ Therefore, Pennsylvania industries may have produced and consumed significantly more electricity than is recorded by the data above.

Established industries consumed the largest amounts of electricity in the mid-Atlantic. For example, in Pennsylvania, iron and steel industries used huge quantities of electricity as did the coke, cement, paper, and glass industries.⁴⁷ Philadelphia also saw the rise of new industrial enterprises focusing on electrical products such as the Electric Storage Battery Company and Atwater Kent Manufacturing Company. Industries in other cities in the region drew on electricity as well. Baltimore manufacturers using electricity intensively included the metal industry, railroads, shipbuilders, and electrolytic works.⁴⁸

Industrial uses of electricity contributed significantly to the entrenchment of the mineral economy in the mid-Atlantic. While the region already had a mature industrial base by the turn of the twentieth century, electricity reinforced the central place of manufacturing by providing a safe and flexible form of energy that could be used to rearrange production processes and increase output. It also gave rise to new industries such as aluminum refining. Abundant aluminum, in turn, was a critical input for other emerging industries such as airplane manufacture. New companies were established to

purchased their power. National Electric Light Association, *The Electric Light and Power Industry in the United States*, 88; Schurr et al., eds., *Electricity in the American Economy: Agent of Technological Progress*, 378.

⁴⁶ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 65.

⁴⁷ *Ibid.*, 78.

⁴⁸ Consolidated Gas Electric Light & Power Company, *1924 Year Book* (Baltimore: Consolidate Gas Electric Light & Power Company, 1925) p. 20.

manufacture electrical equipment including streetcars, motors, and domestic appliances. Finally, the fact that electricity could power smaller motors supported the growth of small-shop industries like the ready-made clothing industry.⁴⁹ Whereas coal and steam engines had encouraged large industrial enterprises, electricity made it much easier for smaller enterprises to consumer mineral power sources.

The use of electricity by the region's industries was characteristic of the mineral economy. Once factories started using electricity, their operators almost always increased their consumption. In just thirty years, industries increased their use of electricity more than fifty-fold (Table 6.1). In addition, electricity could be added without making other sacrifices—many factories still used coal and fuel oil for power as well. Industrial electrification further committed the mid-Atlantic to a development path requiring ever-increasing supplies of fossil fuel energy to maintain.

Domestic Appliances

Electrical appliances in the home consumed a small but growing percentage of overall electrical use between 1900 and 1930. The importance of domestic appliances, similar to the use of petroleum for making lubricants, went beyond the absolute amount of electricity they consumed. The electricity used in homes during this period was relatively minor to begin with, reaching a peak of 7 percent in 1927, and lighting

⁴⁹ In 1929, for example, 22,458 laborers in Philadelphia worked in 774 establishments manufacturing ready-made clothing. The whole industry was powered by 3,866 hp of prime movers, a ratio of roughly 1 hp per 6 workers. The industries that had begun by using coal and oil for power tended to use much more energy per worker. In the same year, the chemical industry in Philadelphia had 7 hp of power for every worker, machinery manufacturers used 4 hp of power for every worker, and sugar refiners used more than 8 hp of power per worker. Pennsylvania. Dept. of Internal Affairs. Bureau of Statistics., *Report on Productive Industries, Public Utilities and Miscellaneous Statistics of the Commonwealth of Pennsylvania for the Years 1929 and 1930* (Harrisburg, PA: Bureau of Statistics, 1931), 233-38.

absorbed a significant amount of this total consumption. However, the expanding use of domestic appliances, particularly during the 1920s, created new patterns of energy consumption that accelerated the transition to the mineral economy.

The adoption of domestic appliances occurred at a far slower rate than the use of electricity for lighting, street railways, and industrial power. In part, this reflected the gradual electrification of American homes during this period. Only 8 percent of American homes were electrified in 1907. This increased to 35 percent of homes by 1920 and 68 percent by 1930.⁵⁰ The mid-Atlantic was not necessarily better off than the rest of the country in this regard: there were over 2,000,000 people living in the area served by the Philadelphia Electric Company in 1919 but only 102,464 were customers, an adoption rate of roughly 35 percent.⁵¹ In addition, even when homes had electricity, the wires were often poorly insulated and incapable of handling a significant load. Power-intensive devices like washing machines and refrigerators required home owners to improve their wiring infrastructure.⁵² Only small devices such as lamps or irons could be plugged into the average residence. Finally, the low levels of home electrification and limited wiring discouraged manufacturers from investing heavily in the mass production of domestic appliances for much of this period. As a result, these technologies were often expensive.

⁵⁰ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, footnote 50, p. 395.

⁵¹ If we assume that the average household had six residents, then about 35% of Philadelphia homes were electrified at this date. Wainwright, *History of the Philadelphia Electric Company, 1881-1961*, 147-48.

⁵² In discussing the limitations of substandard wiring, Ronald Tobey noted that only one-third of American homes had wiring sufficient to power large electric appliances in 1929: “[i]n other words, in the 1920s, nearly two-thirds of the nation's dwellings were *not technologically capable* of being electrically modernized by the simple installation of better illumination and power appliances.” Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*, 33. Italics in original text.

A 1921 survey of 1,300 Philadelphia homes reveals the slow adoption rate for domestic appliances. The National Electric Light Association, an industry trade group, found that the average home only had an iron and a vacuum cleaner. Even in the richest homes, other appliances were rare. Only a third had an electric washing machine or fan and almost none had electric ranges, refrigerators, or radios.⁵³ In the same year, it was estimated that there were a grand total of 565 refrigerators installed in New York, Philadelphia, Baltimore, and Boston, *combined*.⁵⁴

During the next couple decades, however, the use of domestic appliances increased dramatically. In 1922, 34.3 percent of electrified households had electric washing machines and in 1929 the number reached 38.4 percent.⁵⁵ Between 1922 and 1927, the Philadelphia Electric Company sold about \$9,000,000 of appliances, about 40 percent of total sales in the Philadelphia area. Consumers purchased 95,761 irons, 54,047 vacuum cleaners, 21,289 washing machines, 2,377 sewing machines, and 566 refrigerators.⁵⁶ By 1935, the adoption of irons was nearly universal, while about half of American households had vacuum cleaners, washing machines, toasters, and clocks. Roughly a third of Americans had refrigerators and percolators, and many owned waffle irons, ranges, hot plates, and heaters.⁵⁷

⁵³ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 268.

⁵⁴ *Ibid.*, 68.

⁵⁵ Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*, 26.

⁵⁶ Wainwright, *History of the Philadelphia Electric Company, 1881-1961*, 196.

⁵⁷ The actual numbers were 97.2% for irons, 49.8% for toasters, 48.8% for washing machines, 48.3% for vacuum cleaners, 41.6% for clocks, 34.2% for refrigerators, 31.6% for percolators, 19.7% for waffle irons, 18.4% for heaters, 14.9% for hot plates, and 6.8% for ranges: Rural Electrification Administration and Coyle, *Electric Power on the Farm: The Story of Electricity, Its Usefulness on Farms, and the Movement to Electrify Rural America*, 124.

Domestic appliances consumed about 3 to 4 percent of the nation's total electrical consumption, and about half of the electricity consumed in homes, by 1930. Despite this relatively modest number, the beginnings of the widespread adoption of domestic appliances during this period would have significant consequences for the future. As people adopted more and more appliances, it significantly increased their demand for electricity. When homes only had lights and an iron, their monthly demand was around 30 kwh per month. Adding a radio usually added another 10 kwh per month, a refrigerator more than 22 kwh, while a cooking range could consume 123 kwh and a water heater as much as 334 kwh per month.⁵⁸ As domestic appliances became more widespread, homes soon became significant sites of electrical consumption. In 1919, the average Baltimore residential consumer used 391 kwh of electricity per year, but this increased to 635 kwh in 1930 and 902 kwh by 1937.⁵⁹ In Philadelphia, the average home in 1930 consumed 500 kwh per year. By 1960, domestic electrical consumption had skyrocketed to 3,300 kwh per year.⁶⁰

The real explosion in use of domestic appliances came during the 1930s, and as Ronald Tobey has argued, was the result of New Deal policies rather than the invisible hand of the market. One of Roosevelt's major platforms was a belief that electrification was linked to social progress and that it was the role of government to increase its availability to those who did not have service from private utilities. He implemented several programs that helped increase the percentage of Americans with electric service

⁵⁸ Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*, 158.

⁵⁹ Consolidated Gas Electric Light and Power Company, *1928 Annual Report* (Baltimore: Consolidated Gas Electric Light & Power Company, 1929), p. 6. Consolidated Gas Electric Light and Power Company, *1937 Annual Report* (Baltimore: Consolidated Gas Electric Light & Power Company, 1938), p. 8.

⁶⁰ Wainwright, *History of the Philadelphia Electric Company, 1881-1961*, 390.

and appliances from 20 percent to 80 percent. Most of these programs, such as Title I of the National Housing Act provided cheap financing that allowed homeowners to obtain credit for installing wires and purchasing appliances.⁶¹ After seeing the success of these government programs, Tobey argues that utilities began to see the value of offering consumers credit and began implementing similar programs themselves.⁶²

Domestic appliances had significant consequences for home life. Billed as labor-saving devices, home economists and other experts hoped these technologies would free women from the drudgery of the home. As the historian Ruth Schwartz Cowan has shown, these utopian dreams were never achieved. Refrigerators, vacuum cleaners, and washing machines changed the type of work that middle-class housewives performed, and even increased their productivity, but they did not reduce the amount of time spent tending the home. Instead, these new appliances replaced domestic servants for middle-class women, leaving housewives in charge of tasks that previously occupied several workers. The nature of housework had changed, but it had not disappeared.⁶³

The intensive use of electricity in the home represented an important shift into the mineral economy. Energy had always been part of home life, whether for cooking, chores, or even the manufacture of goods under the putting-out system. Over the course of the nineteenth century, fossil fuels had come to replace organic energy sources for much of the mid-Atlantic's heating, cooking, and lighting needs. However, almost all the labor in the home required the power of human muscles before the introduction of

⁶¹ In order to handle the power demand of many appliances, homes often had to have better wires installed. Tobey, *Technology as Freedom: The New Deal and the Electrical Modernization of the American Home*, 107.

⁶² Ibid.

⁶³ Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*.

electric appliances. The adoption of irons, vacuums, washers, stoves, sewing machines, and other appliances marked the first time that mineral sources of energy were used to provide mechanical power in the home. And characteristic of the mineral economy, consumption of electricity in the home increased dramatically over the course of the twentieth century. By 1950, residential consumption had increased to 25 percent of the nation's electrical use and by 1986, as much electricity was being used in the home as in industries.⁶⁴

This shift was amplified by the use of electricity in leisure activities. In an organic economy, where labor was typically the product of one's own muscles, leisure was often characterized by the absence of energy expenditure.⁶⁵ The application of electricity to radios, movie projectors, phonographs, and even amusement parks changed this logic. The use of mechanical energy did not require personal exertion and therefore encouraged the development of leisure technologies. Like domestic appliances, technologies such as radios significantly expanded how and where mid-Atlantic residents used fossil fuel energy. Electricity helped extend the mineral economy into home and leisure life as well as industrial practices.

Collectively, the consumption of electricity in all domains by mid-Atlantic residents broke the organic economy's relationships between land and energy. For example, in 1927, Pennsylvania produced 11,870 million kwh of electricity—more than

⁶⁴ Calvin Burwell and Blair Swezey, "The Home: Evolving Technologies for Satisfying Human Wants," in *Electricity in the American Economy: Agent of Technological Progress*, ed. Sam H. Schurr, et al. (New York: Greenwood Press, 1990), 250.

⁶⁵ This is not an absolute distinction. Organic sources of energy like human muscles were used for dancing and some mineral sources of energy were used for lighting purposes. However, new technologies like radios and phonographs dramatically increased the use of mineral energy used in leisure activities.

10 percent of the nation's total.⁶⁶ Over 85 percent of this energy (about 10,250 million kwh) was generated by burning fossil fuels.⁶⁷ To replace this energy with firewood would have required a dedicated land area of 7,917,000 acres or 12,317 square miles, over a quarter of Pennsylvania's land mass.⁶⁸ Moreover, Pennsylvanians had already tapped many of the state's most promising hydroelectric sites and there was little technology in place to transform other forms of solar energy into electricity. There were no other organic sources of energy capable of meeting Pennsylvania's recently acquired energy needs.

While it would have been possible to set aside land for trees that would be burnt to produce electricity, it would have required Pennsylvanians to face trade-offs characteristic of the organic economy. Electricity was only 11.5 percent, or less than one-eighth, of the nation's total energy supply in 1929.⁶⁹ Electricity replaced some uses of energy, such as when electric lights eclipsed kerosene or electric motors were substituted for steam engines in manufacturing, but it only made a small dent in other categories such as heating, cooking, and railroad transportation.⁷⁰ In other words,

⁶⁶ United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1927*, 12.

⁶⁷ Pennsylvania's central utility stations produced 13.6% of their kwh through hydroelectricity (Pennsylvania's central utility stations generated 63.2% of total electrical production): Ibid., 47. The ratio was likely similar in industrial production.

⁶⁸ In 1927, 1.84 pounds of coal were needed to produce a kwh of electricity. This means that 10,250 million kwh would require 9,430,000 tons of coal. As a cord of wood had the energy equivalent of 4/5 of a ton of coal, 11,875,000 cords of wood would be needed to replace the coal. Since 2/3 of an acre was needed for the sustainable production of a cord of wood, 7,917,000 acres, or 12,317 square miles of woodland would be needed. Average coal consumption from: Ibid., 33. Heat equivalents of wood and coal from: Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 51. Wood yield data from: Williams, *Americans and Their Forests: A Historical Geography*, 106.

⁶⁹ Schurr et al., eds., *Electricity in the American Economy: Agent of Technological Progress*, 374.

⁷⁰ Around 1930, some American railroads began to electrify, but their total energy demand of less than a billion kwh was under 1% of total production: United States Bureau of the Census, *Census of Electrical Industries: Street Railways, 1927*, 66..

Pennsylvania's electrical consumption would have required more than a quarter of its land area—along with its best water-power sites—but provided less than an eighth of the total energy supply.⁷¹ This was impossible in an organic economy. By 1930, the use of electricity in Pennsylvania had pushed the state further into the mineral economy.

Conclusions

Winners and Losers

Electricity produced a number of costs and benefits for mid-Atlantic residents but these were not distributed equally. Similar to the energy landscapes of coal and oil, city residents enjoyed the majority of benefits while those in rural areas experienced the bulk of the costs, mostly in the form of environmental degradation.

City residents benefited the most from electrification. All the major classes of electric consumption—lighting, street railways, industrial power, and domestic appliances—were commonly used by urbanites. It was typical for a city resident in the late 1920s to wake up, turn on a light, ride a streetcar to work, use an electrically driven machine at work, and listen to a radio at night. Given the wide variety of uses of electricity in cities, it is no surprise that consumption was highest in urban locations. For example, in 1917, people living in cities with more than 200,000 residents consumed 59.1

⁷¹ In 1925, Pennsylvania used nearly 40 million tons of coal for all uses, more than four times the estimated use of coal to generate electricity. Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 59.

percent of the energy used in lighting and 52.0 percent of the energy used for power that was sold by utilities while representing only 30 percent of the population.⁷²

The electrification of urban transport, in turn, promoted the development of suburban living. On the whole, those living in suburbs experienced most of the effects of electrification in a manner that was similar to those in the city core. Because suburbs were generally created along the paths of electric railway companies, most suburbanites had easy access to electrical service for home lighting and personal transport. Because services like commercial laundries were less often available in suburbs than in the city core, suburban residents were more likely to use domestic appliances such as electric washing machines.⁷³ By contrast, because there were fewer industries in the suburbs, much less electricity was used for manufacturing in these locations.

Within cities and suburbs, socio-economic divisions structured the allocation of benefits. Middle-class residents may have derived the greatest benefits from electrification. This group was most likely to use streetcars to move to the suburbs and escape the congestion and pollution of the urban core. In addition, middle-class residents relied more heavily on domestic appliances than the wealthy who had greater access to servants or the poor who could not afford them. The electrification of the factory may have benefited all by providing better light and a quieter and safer place to work, but most of the financial benefits were returned to the wealthy managers and stockholders. Lower-class residents saw few benefits from electrification. In fact, by being stranded in the urban core without middle-class residents to share the tax burden and help advocate

⁷² The population estimate for these cities was 31,035,214 while the total population was 103,635,306. United States Bureau of the Census, *Census of Electrical Industries: Central Electric Light and Power Stations, 1917*, 34, 38.

⁷³ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 383.

for improved city services, electrification may have left many lower-class urbanites worse off.

Electricity outside of cities and suburbs, by contrast, was a rarity before the New Deal programs of the 1930s. In 1925, for example, less than 12 percent of Pennsylvania farms had access to electricity.⁷⁴ Even when electricity was available on the farm, it did not make a big impact on agricultural practices. Except for the widespread use of electricity for irrigation in the western United States, farmers rarely chose to electrify their operations. Although investors developed electric machines for hoisting hay, grinding feed, sharpening tools, or incubating eggs, these were not commonly used. Even in the rare cases when transmission wires reached farms, most rural residents chose to use electricity for lighting and domestic appliances rather than agricultural production. The first purchases usually mirrored what city dwellers bought: lights, irons, and radios.⁷⁵ When farmers chose to invest in energy technology, gasoline-powered vehicles were a much more common choice. Given that it was estimated that 50 percent of farm work was in the fields (mostly plowing) and 22 percent was for hauling, vehicles were a more compelling choice for most farmers.⁷⁶ Thus, electrification may have made life on the farm a little more comfortable but it did little to revolutionize agricultural practices during this time period.

Rural residents benefited the least from electrification and also paid many of the environmental costs. For example, the development of the Holtwood Dam ruined the

⁷⁴ Pennsylvania. Giant Power Survey Board., Pinchot, and Ettinger, *Report of the Giant Power Survey Board to the General Assembly of the Commonwealth of Pennsylvania*, 37.

⁷⁵ Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 319.

⁷⁶ Rural Electrification Administration and Coyle, *Electric Power on the Farm: The Story of Electricity, Its Usefulness on Farms, and the Movement to Electrify Rural America*, 66.

local fishing industry. The extraction of coal, which provided most of the region's electricity, contributed to the environmental degradation of the anthracite and bituminous coal regions. For cities, the environmental record was more mixed. Although urban generating stations emitted a fair amount of smoke, they replaced the need for many organizations to operate their own steam engines. Therefore, urban generating stations may have lowered the overall amount of smoke pollution in cities.

In the end, the distribution of costs and benefits of coal, oil, and electricity showed remarkable similarities. The transport of cheap and abundant energy to cities provided urban residents with access to cheap and abundant heat, power, and light thereby creating opportunities for wealth, industrial growth, and labor saving devices. Rural residents rarely had comparable access to mineral energy sources. Moreover, those living in the rural sites of energy production typically faced most of the environmental costs while receiving relatively few of the benefits. Electrification reflected and reinforced these unequal distributions of costs and benefits of the mid-Atlantic's mineral energy practices.

Creating Dependence

The transport and consumption of electricity contributed to the mid-Atlantic's dependence on fossil fuel energy. When it was first introduced, homeowners, store managers, and factory operators could choose whether or not they wanted to adopt electricity for heat, light, and power. By 1930, however, powerful structural forces made it difficult for people to live without electricity. Factories, stores, urban transport

systems, and homes all needed continually increasing supplies of electricity to maintain their operations.

In the factory, electricity provided a myriad of benefits that ensured its ongoing consumption for manufacturing purposes. First, electricity was an efficient form of power that lowered costs because motors could be started and stopped quickly, versus steam engines that needed to be operated continually. Second, the fact that electricity could be delivered to small motors throughout the factory floor gave rise to new manufacturing processes such as assembly lines that further cut costs and increased output. Finally, a whole host of industries were predicated on the use of electricity. Manufacturers of metals such as aluminum and ferro-silicon required huge inputs of electricity. In addition, many smaller enterprises found that electric motors in devices such as sewing machines and power tools provided a form of energy that was much more practical than large steam engines.

In the context of a profit-seeking economy, the idea of abandoning the benefits of electric power for industrial purposes is difficult to imagine. Such a decision would have put most enterprises at a significant economic disadvantage vis-à-vis their competitors. For industries that could not effectively use alternative energy sources—like aluminum refining—it would have meant going out of business. Using electricity did not guarantee a firm's success, but its absence in most industries would have been an economic liability.⁷⁷ Not only would it have been illogical for factory operators to abandon

⁷⁷ There is not a direct connection between electrification and profitability, but the two were related processes. The fact that only 5% of motors were powered by electricity in 1899 and more than 80% were in 1930 indicates that electrification offered clear economic benefits. Moreover, this period saw a steady increase in the application of mechanical power. In 1899, there was 2.14 horsepower installed per worker in manufacturing establishments, and only .1 hp of this was electric. By 1925, there was 4.26 hp per

electricity, it would have been illegal. Corporate boards were required to maximize shareholder value, preventing them from making such a decision if it would hurt the company's economic prospects. Overwhelming economic and legal pressures, therefore, provided powerful incentives for manufacturers to continue using electrical power.

The same logic shaped the choices of store owners. Electric lighting was an important part of advertising and technologies such as elevators and fans made stores more desirable places to shop. Electricity, therefore, could provide an enterprise with a competitive advantage. Once one store began to use electricity, competitive dynamics provided steady pressure for other store owners to use electricity lest they get left behind.

Streetcars provide another clear example of the ways that mid-Atlantic residents became dependent on electricity to maintain their way of life. Electric streetcars made suburban living practical for large numbers of people. Once people moved to the suburbs, they no longer necessarily lived within a couple miles of work locations and stores. For many suburban residents, it was impractical to use their muscles for everyday transport needs. Instead, they became dependent on mineral sources of energy for daily travel to and from home, work, and stores. At first, electric streetcars provided this service, although automobiles became the preferred mode of personal transport beginning in earnest in the 1920s and 1930s.

Many hoped that suburban living would lead to a revitalization of republicanism, typified by the independent farmer. However, suburban living was anything but independent. Once in suburbs, people required mineral energy sources for daily

worker and 3.12 hp was electrified. Schurr and Netschert, *Energy in the American Economy, 1850-1975: An Economic Study of Its History and Prospects*, 187; National Electric Light Association, *The Electric Light and Power Industry in the United States*, 87.

transport. Moreover, they also came to depend on electrical appliances in the home to supplement services that were no longer available. For example, those living in the urban core could send clothes to commercial laundries, but in the suburbs it was much more common to use electric washing machines in the home. In addition, because suburban houses tended to be larger and were less often attached to other buildings, they required more energy to heat (and later cool, when air conditioning became common). As a result, suburban homes perpetuated a lifestyle requiring significant amounts of fossil fuel energy to maintain.

In the home, electricity helped give rise to new social and cultural practices that encouraged continually increasing energy consumption. The small motors in domestic appliances made it practical for people to use fossil fuels for tasks requiring mechanical energy such as cleaning. A similar shift occurred in leisure practices. Beginning with the amusement parks at the end of streetcar lines and continuing with the development of movie projectors and radios, entertainment increasingly involved the use of fossil fuel energy. In other words, using more electricity in the home was linked to saving one's own labor, if not time, enjoying a greater range of leisure opportunities and a higher standard of living. Relinquishing these benefits would have made little sense to most homeowners. Actual events reflect the logic of ever-increasing consumption—home residents in Philadelphia increased their consumption of electricity more than six-fold between 1930 and 1960.⁷⁸

By 1930, a typical mid-Atlantic resident living in an urban or suburban area was likely to consume fossil fuel energy working, traveling, maintaining a household, and

⁷⁸ Wainwright, *History of the Philadelphia Electric Company, 1881-1961*, 390.

relaxing. For those living in mid-Atlantic cities, there were almost no remaining vestiges of the organic economy constraining their actions. Cheap and abundant electricity, transmitted to homes, stores, and factories, had become a necessary part of life.

Conclusion

By 1930, the mid-Atlantic had developed a full-fledged mineral economy. Fossil fuels provided the large majority of the region's energy needs, not organic sources like muscles and wood. Canals, pipelines, and wires had transformed urban locations, which had been energy-scarce in an organic economy, into sites of energy super-abundance. A rural and commercial society a century before, the mid-Atlantic was now an urban and industrial superpower. The negative feedback loops of the organic economy had given way to synergistic relationships between fossil fuels and continual economic growth.

The creation of new energy landscapes structured how, when, and where these changes happened. Without canals, pipelines, or wires, the development of an energy-intensive society would have required people to move to the anthracite regions, the oil regions, or the banks of rivers like the Susquehanna. Such a development path was theoretically possible. Pittsburgh, for example, developed as an important industrial setting based largely on the cheap and easy availability of bituminous coal and river transport. However, while Pittsburgh was connected to mid-Western and southern markets via the Ohio and Mississippi rivers, most of the areas where anthracite coal, petroleum, and hydroelectric power could be found lacked comparable transport facilities.¹ These locations offered abundant energy, but little else. It is not clear that these rural regions could support have supported the patterns of synergistic growth between among residents, workers, and markets that characterized the growth of New York, Philadelphia, and Baltimore between 1820 and 1930.

¹ As discussed in Chapter 5, transportation along the Susquehanna River was severely limited by the heavy falls along the river's last 35 miles.

As we know, canals, pipelines, and wires *were* built, resulting in the particular development patterns described throughout this work. By transporting coal, oil, and electricity long distances, these energy landscapes created one of the most salient features of the contemporary world: the geographic separation of energy production from its consumption. Americans are so accustomed to cheap and abundant fossil fuel energy available at almost any time and place that we forget this is neither a natural nor inevitable feature of the world. The need for energy, however, is not just an ideology or assumption; it is literally a concrete fact of our living patterns. The nation's built environment—large homes in the suburbs, an extensive road and highway system, sprawling cities—can only function with energy inputs from far away. The energy landscapes of the mineral economy are as important today as they were in the mid-Atlantic between 1820 and 1930.

Reflections on Coal Canals, Oil Pipelines, and Electricity Transmission Wires

Looking back on the history of canals, pipelines, and wires in the mid-Atlantic, we can discern several patterns. First, there were differences within each class of technologies, based on who owned them, how they were operated, and where they were built. While they all contributed to the development of a mineral economy in the mid-Atlantic, their effects were not linear, nor were the benefits and costs distributed equally. For example, the transmission wires from the Holtwood dam transported cheap energy to Baltimore but not to Philadelphia, thereby supporting the former city's industrial growth. Standard Oil used its control over transport infrastructure to achieve a near-monopoly position in the petroleum industry thereby funneling large amounts of profit into the

hands of a very small group of investors. The Schuylkill Navigation Company lacked corporate privileges to mine coal as well as to ship it, thereby leading to a different pattern of development in the Schuylkill Valley than the Lehigh or Wyoming coal regions.

Moreover, the social impacts of canals, pipelines, and wires could change after they were built. When the Tide-Water Company reached an agreement to operate cooperatively with Standard Oil, the ramifications of the pipeline shifted. It still shipped oil from western Pennsylvania towards the east coast, but the pipeline was no longer part of an attack on Standard Oil's monopoly. The pipeline ceased to be a radical technology capable of altering the industry structure. Instead, it became a conservative investment preserving the power of a limited group. Thus, the ownership and operation of these technologies mattered as much as their physical capabilities.

There were also differences between these classes of technologies. Infrastructure systems can be distributive (where there is a one-way flow outwards from a central point towards many endpoints), accumulative (where the flow is one-way from many points towards a central location), and communicative (where flow can happen in many directions and along many points). Electricity, water, and radio are examples of distributive systems, sewage and garbage collection are accumulative systems, and telephone wires and highways are communicative systems.² Canals best fit the model of communicative technologies, as they permit the flow of many goods in two directions. Pipelines and wires are both distributive systems, although there were important technological differences between the two. Electricity transmission wires offered a much

² Daniel Jonsson, "Sustainable Infrasytem Synergies: A Conceptual Framework," *Journal of Urban Technology* 7, no. 3 (2000). My thanks to Arne Kaijser for introducing me to Jonsson's ideas.

greater potential for a two-way flow of power and to provide service to places along the path of the wire.³ Pipelines, by contrast, have a unidirectional flow and rarely deliver oil to places along their path.⁴

These technical features of energy landscapes structured regional development. For example, canals supported a thriving iron trade along their paths because they facilitated the cheap transport of raw materials to forges and finished products to markets. Electricity transmission wires allowed for a similar possibility, as potential users along the paths of wires could access the wire through a small substation that transformed the electricity to a safe voltage. However, even though some transmission wires operated this way, particularly in California, this does not seem to have been a common practice in the mid-Atlantic.⁵ Therefore, electricity transmission wires in the mid-Atlantic do not seem to have greatly benefited those living along their paths. The same is true for oil pipelines; I have seen no evidence that significant quantities of oil were delivered anywhere along the line, and it is likely that these technologies did not stimulate the growth of the regions between their endpoints.

State and federal governments played important, although not primary, roles in the development of energy transport infrastructure. Most of the capital came from private investors—the Pennsylvania State canal system is the one exception—but government

³ Many transmission wires were built with the explicit intention of sharing electricity between utilities when their peak loads occurred at different times. This was also true for the wires between the Holtwood Dam and Baltimore. While most of the electricity went from Holtwood to Baltimore, the steam stations in Baltimore sent power to Holtwood at times of low river flow.

⁴ Reversing the flow of oil along a pipeline required building new pumping stations, a significant capital investment. In practice, I have found no evidence that this ever occurred during the time period of this study.

⁵ This was much more common in California, where farmers in the central regions of the state were able to get electricity to use in irrigation from the transmission wires connecting the hydroelectric dams in the Sierra Nevada Mountains with San Francisco and Los Angeles. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940*, 292-93.

decisions structured the development of these technologies and their operations.

Land rights were particularly important for developers of infrastructure. By granting the rights to develop the Lehigh River to Josiah White and Erskine Hazard, the Pennsylvania Legislature facilitated the development of the Lehigh Canal. By refusing to grant eminent domain privileges to oil pipelines until after the completion of the Standard Oil network, the same body made it more difficult for entrepreneurs to develop pipelines. Electricity companies also sought, but failed, to receive eminent domain privileges for transmission lines during the 1910s.

The role of government was by no means limited to land rights, however. Government agencies encouraged energy consumption by sponsoring experiments with new energy sources (such as the Navy's testing of petroleum as a fuel oil in 1862) or facilitating the development of more efficient networks (by funding the Superpower Survey in 1919). They gave energy organizations special privileges that made it easier to acquire capital or enter the trade (such as corporate privileges for iron forges using anthracite coal in Pennsylvania). At various times the federal government protected domestic energy industries by raising tariffs on imported energy sources. And while regulation was heavily resisted by many energy companies, it was associated with a number of privileges such as monopoly rights for electric utilities. Collectively, the myriad decisions of government agencies facilitated the development and dispersion of new energy practices.

Another pattern that emerges from this study is that the first efforts to implement transport infrastructure usually ended up being financial failures. By Josiah White's count, there were at least seven different acts passed to improve the Lehigh River before

his company succeeded. The Tide-Water pipeline was completed only after other efforts such as the Pennsylvania Transportation Company's proposed line to Baltimore and Benson's efforts with the Seaboard Pipe Company came to naught. The men who financed 80 percent of the construction of the Holtwood Dam lost their equity stakes when the company collapsed in the Panic of 1907. The first actors, therefore, usually failed. This pattern suggests a lesson relevant to the present day: we should not see it as a sign of failure if early attempts to create renewable energy systems do not succeed. Early failures with fossil fuel energy ended up laying crucial groundwork for the success of organizations that rose up from the ashes.

Finally, in the mid-Atlantic, energy supply led demand, not vice versa. While the adoption of coal in Britain was largely driven by a scarcity of other energy sources, this was not the case in America. The boosters associated with each energy source needed to convince customers to adopt new energy practices, learn new techniques of harnessing power, and change traditional ways of doing things. In many cases, this was an easy argument to make. Anthracite coal could keep a house warmer for less money. Kerosene offered better light at a cheaper cost. Electricity gave factory owners more flexible over work-space design. However, most of the time there was not a pent-up demand that fossil fuel energy satisfied. Instead, people had to be shown and convinced that the new practices made sense. Supply was the main driver, not demand.

The Logic of Intensification—Energy as Labor versus Energy as Commodity

It would be a mistake, however, to focus entirely on the differences between canals, pipelines, and wires. When seen in historical hindsight, their similarities are

ultimately more significant. Collectively, the most important consequence of building energy transport infrastructure in the mid-Atlantic between 1820 and 1930 was to set in motion a pattern of intensified fossil fuel consumption. Canals, pipelines, and wires made it possible and easy for residents of the mid-Atlantic to use massive amounts of fossil fuel energy. By doing so, they contributed to a crucial shift from a system where it was logical to conserve energy to one where it made sense to consume ever-increasing supplies of fossil fuels. Simply put, energy landscapes gave rise to a logic of intensification.

In an organic economy, the default behavior is to be conservative in one's use of energy. This behavior is driven by the fact that the muscles of humans and animals supply most energy in this system. As a result, using energy requires personal exertion. In most organic societies, the vast majority of the society's heat energy comes from firewood, which requires considerable labor to chop, split, stack, and haul—as much as a third of a man's working hours.⁶ Even the use of animals requires human effort to direct the labor and to feed, clean, and house them. In other words, energy is largely synonymous with personal labor. When one's own sweat is involved, there is a significant incentive to limit one's needs for energy or to discover shortcuts. This is why people living in organic economies tend to congregate in places where easy energy is available or there are ways to avoid energy expenditure, such as the banks of rivers that dramatically lower the labor of transporting goods to market and provide a power source. Moreover, there are finite limits to the expansion of available energy in an organic economy. There are only so many acres of forest, streams with falling water, and land

⁶ This calculation is from colonial American times. Ruth Schwartz Cowan, *A Social History of American Technology* (New York: Oxford University Press, 1997), 39.

for grazing. Once the available resources are being utilized, their output cannot be expanded, thereby encouraging people to do more with less.

By transforming the built environment of the mid-Atlantic so that it was simple and cheap to transport fossil fuel energy from remote regions to urban centers of consumption, canals, pipelines, and wires reversed the logic of the organic economy. The widespread use of coal, oil, and electricity broke the links between energy and the exertion of one's own muscles. Instead of energy being synonymous with labor, it was transformed into a commodity product. This led to a new calculus of decision-making—one that would appear absurd from the perspective of an organic economy.⁷ Cost and availability became the primary factors influencing how much energy was consumed. Instead of finite limits to energy growth, canals, pipelines, and wires ensured that fossil fuels got simultaneously cheaper and more abundant as their use increased. From this new perspective, using ever-increasing amounts of energy became a socially logical behavior.

This shift can be seen in the difference between the parable of the pin-makers in Adam Smith's *Wealth of Nations* and the industrial logic of the late nineteenth and early twentieth century. Smith's pin-makers—in an organic economy—increased their profits through division of labor and the adoption of more efficient processes, thereby *saving* the application of energy. In other words, shortcuts that were more efficient led to economic success. By contrast, the economic growth that was most characteristic of

⁷ According to Sieferle: "An important characteristic of the fossil energy system was and is energy superabundance. Many characteristics of hunter-gatherer and agrarian societies are attributable to energy being in short supply and the need to be very economical with it. . . . The enormous abundance of energy in the industrial system led to the formation of behaviour that appears absurd from an energy point of view." Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution*, 45.

industrialization was based on the substitution of fossil fuels for other production inputs like labor or capital. The great enterprises of industrialization, such as railroads and iron foundries, required massive amounts of energy for heat and power. When ever-increasing supplies of energy at continually decreasing costs were available, greater profitability arose from increasing the consumption of energy, not the reverse.

The evidence that mid-Atlantic residents responded to this new logic by intensifying their consumption of fossil fuel energy is overwhelming and has been presented throughout this work. Once people got a taste of the benefits of using coal, oil, and electricity, their appetites grew dramatically. The energy landscapes of canals, pipelines, and wires were at the center of these changes. By transporting energy cheaply and abundantly to markets, they initiated a synergistic cycle: canals, pipelines, and wires made new energy supplies available, thereby giving people the incentive to discover new applications. Once boosters established new practices, demand for energy increased, necessitating the expansion of supply. Steady expansions of transport infrastructure networks ensured that energy could be continually supplied in increasing amounts and at a decreasing cost.

It was not historically inevitable that new energy landscapes would lead to the intensification of fossil fuel consumption. Nor were these changes purely the result of conscious human choices. However, many factors made this outcome overwhelmingly likely. Simply put, using fossil fuels offered so many benefits and came with so few noticeable costs that intensification was practically a foregone conclusion. The presence of a profit-seeking economic system, inter- and intra-regional competition, boosters, and

thousands of individual decisions dramatically overwhelmed any possible objections.

Let's look at each of these in turn.

A profit-seeking economic system in the mid-Atlantic played a significant role in making increased fossil fuel consumption a socially logical behavior.⁸ First, it provided incentives for the owners of canals, pipelines, and wires to maximize their investments. All of these technologies were expensive and represented significant sunk costs. In order to pay off bonds and attract additional investments, the companies managing transport infrastructure had powerful financial incentives to operate these technologies at their maximum capacity and expand their throughput. Second, businesses with access to cheap fossil fuels found that substituting energy for labor or using large amounts of heat in manufacturing operations increased their profitability, thereby encouraging these organizations to use more. Finally, the profit-seeking system fueled the rapid expansion of energy production by driving the speculative booms that were common practice in Pennsylvania's coal and oil fields.

Second, the mid-Atlantic did not operate in isolation. There was intense economic competition intra- and inter-regionally. Philadelphia, New York, and Baltimore fought with each other to control trade. States competed to attract industries and the United States sought to outpace its European rivals. Because energy was linked to economic growth, government agencies adopted policies encouraging the consumption of fossil fuels. Pennsylvania adopted a law giving special corporate privileges to

⁸ Whether the economy of the mid-Atlantic was truly "capitalist" throughout this time period has been debated extensively. Walter Licht argues that in the course of the nineteenth century, America passed "from a mercantile to an unregulated and then to a corporately and state-administered market society." For the purposes of my argument, it is less important whether the economic system was mercantile, market-oriented, or capitalist. The key point is that the pursuit of profit was widely considered to be the point of business enterprises. Licht, *Industrializing America: The Nineteenth Century*, xvi.

companies manufacturing iron with anthracite in the 1840s, New York and Maryland passed free pipeline bills before Pennsylvania (because it would encourage the flow of oil to their states), and the United States government gave financial support for the Superpower survey in the 1920s because of concerns over the electrical supply during World War I. Competitive dynamics propelled the coal, oil, and electricity industries forward.

Boosters were a third force driving the adoption of new energy supplies. Before coal, oil, and electricity could be used in homes and factories, consumers had to be taught how to use new energy sources and be convinced of their value. Boosters developed new applications and introduced people to their use. The officers of the transport companies were important boosters in the mid-Atlantic and were joined by scientists, inventors, politicians, capitalists, and trade organizations. Boosters had complex motives. Some were driven by pursuit of profit, others by intellectual curiosity, and many by regional pride. Collectively, their efforts were crucial to creating markets for new energy supplies.

The development of a mineral economy could not have happened without the aggregation of thousands of individual decisions. Business owners had to make choices about where to site their factories and what types of power to use. Homeowners had to decide how to heat and light their homes and whether they would move to the suburbs. While individuals with free choice and autonomy made these decisions, their options were heavily structured by the region's energy landscapes. It made sense to establish an energy-intensive factory in a city only if there was sufficient power available. One could not heat a home with coal if canals were not bringing thousands of tons to urban cores. It

was not practical to move to the suburbs if an electric streetcar network would not make it convenient to get to work. Individuals made these choices, but did so in the context of a society designed for them to use fossil fuels.

There was little to counter these powerful forces encouraging the growth of fossil fuel consumption. The benefits of mineral energy sources—increased economic output, warmer homes, better light, increased ability to travel, more abundant and cheaper goods—overwhelmed the costs as long as energy was cheap and abundant. The environmental costs of energy production were the most obvious negative result of new energy practices during this era. However, canals, pipelines, and wires physically separated consumers from these effects. Most of the environmental degradation occurred at distant sites of production. The anthracite coalfields and oil regions sustained extensive environmental damage through strip mining, loss of forest cover, spilled petroleum, and the release of toxins brought to the surface during mining operations. Damming the Susquehanna River ruined the local fishing industry. Urban consumers of energy, by contrast, experienced fewer harms. Anthracite coal burned relatively cleanly, a kerosene lamp produced less soot than a candle, and electricity released no pollution at the site of consumption. In other words, transport infrastructure rendered the worst social costs invisible to the main consumers.

The only other constraint of significance during this period was the persistent appeal of republicanism as a social ideal.⁹ Particularly during the antebellum era, the drive for an urban and industrialized nation promoted by certain boosters was partially countered by believers in the Jeffersonian ideal of the self-sufficient farmer. By

⁹ For a review of republicanism, see Rodgers, "Republicanism: The Career of a Concept."

advocating moderated growth and a rural ideal, republicans were linked much more closely with an organic economy than a mineral one. Even as late as the 1920s and 1930s, Gifford Pinchot and Franklin Roosevelt sought to use rural electrification to revive the appeal of life in the countryside. However, while it is possible that republicanism tempered the speed at which a mineral economy developed in the mid-Atlantic, it ultimately failed to halt its development. The many immediate advantages of using fossil fuel energy proved too great for any serious challenges to the spread of these practices.

In the end, the establishment of a social and economic logic favoring continual intensification was one of the most significant historical patterns to emerge from the construction of new energy landscapes. While this was a multifaceted process involving a wide variety of actors, forces, and decisions, coal canals, oil pipelines, and electricity transmission wires were the material drivers of these new practices. Without these technologies, the development path of the American mid-Atlantic would have looked profoundly different.

Whither the Mineral Economy?

Over the past several decades we have only deepened our dependence on mineral energy sources. However, two consequences of the mineral economy are becoming remarkably clear. First, it cannot last forever. While we do not know exactly how much carbon we have left to burn, we know that fossil fuel stocks are not infinite.¹⁰ At some

¹⁰ The contested nature of reserve estimates—particularly their unreliability and the role of state secrets in confounding estimates—is discussed by Timothy Mitchell in “Carbon Democracy,” (paper presented at University of Pennsylvania History & Sociology of Science Workshop, Philadelphia, PA, October 2008.)

point in the future—be it in a few decades or a century or more—we will run out of cheap and abundant fossil fuel energy. The era of the mineral economy will end sooner or later. Second, overwhelming scientific evidence suggests that if we actually use our remaining fossil fuels, we will create climate changes that are not conducive to sustaining human life. We are now in a position where we simultaneously have too much and too little fossil fuel energy.

So, what comes next? A review of the history of energy landscapes in the mid-Atlantic suggests at least three lessons. First, we need to prepare for the end of the mineral economy. We cannot continue forever to derive our energy supplies from stocks stored over millions of years. Instead, we need to return to a system where we obtain our energy from capturing solar flows. In other words, we need to think once again about some of the features of the organic economy. In particular, we need to adjust our energy consumption patterns to our technological abilities to extract useful energy from solar flows and come to terms with the limits of organic energy sources.

In the last two hundred years, we have developed more sophisticated ways of capturing solar energy, such as hydroelectric facilities like the Holtwood Dam, arrays of wind turbines, or solar farms of photovoltaic cells. Biotechnology research into biomass growth and even growing fuel from ocean algae offer the potential to increase our supply of useful energy. However, all of these energy systems still face certain limits characteristic of the organic economy. There are only so many streams to provide hydroelectric power and both sunlight and wind vary in space and time.¹¹ Gains in

¹¹ The sun shines brightest in certain places and the wind blows most regularly in others. Moreover, both sunlight and wind patterns are subject to daily and seasonal variations.

biotechnology still require the allocation of land area, creating potential conflicts about whether land should be used for energy versus food production.

What are the implications of shifting to organic energy sources? First, it means we need to think more carefully about the relationships between population and energy. If we need to use landmass to provide energy this will decrease the number of humans that the land can support. We will need to make decisions about whether to support small populations with relatively large supplies of energy or large populations with smaller supplies. In other words, there may need to be trade-offs between total energy supply and population. Malthus could rear his head once again.

Second, we need to shift the social logic of energy consumption. Despite the clear dangers of global warming and inevitability of fossil fuel depletion, the social logic of intensive fossil fuel consumption has not changed. Energy consumption is still linked with economic growth, labor-saving production, and a more comfortable existence. Fossil fuels remain cheap and abundant, and the environmental consequences of their production and consumption are treated as externalities. Moreover, while intensive fossil fuel consumption was once largely restricted to America and Europe, the recent increases in nations like China and India greatly exacerbate the problems facing our planet. Unless we address the structural conditions that make the benefits of fossil fuel consumption outweigh its costs for so many people, it makes little sense to expect billions of individuals to alter their fossil fuel consumption practices.

There are several carrots and sticks we have available as a society to influence how people think about energy consumption. On the carrot side, we can implement policies that favor the development of hybrid forms of renewable energy sources like the

Holtwood dam. This will give people practical alternatives to consuming fossil fuel energy, making conversion much more feasible. We can also use policy to build the true costs of fossil fuels into the market through mechanisms such as carbon caps. This will increase the price of fossil fuels to consumers, having the twin effect of discouraging further consumption and making renewable energy sources more cost-competitive. Third, we can establish requirements for utilities to derive certain percentages of their energy from renewable sources. Of course, people have been advocating such proposals for years with relatively little success. Hopefully, increasing social awareness of the problems of our energy practices will give these proposals additional momentum in the coming years.

Third, we should use infrastructure developments to initiate a transition to a system of sustainable and renewable energy supplies. As I have shown throughout this work, the transition to a fossil-fuel intensive society was actively created by capitalists, boosters, and, of course, energy landscapes. Canals, pipelines, and wires transformed the natural world to make coal, oil, and electricity cheap and abundant at sites far removed from their production. In short, they made using fossil fuel energy easy. Not surprisingly, people chose to use this energy and created a world that depended on its continued availability. Homeowners purchased houses in the suburbs where they would need mechanical energy to get to work, businesses invested in capital equipment designed to consume power, and cities grew to support factories and residential populations that could not be fueled solely by the products of their hinterlands. These developments required the continued availability of fossil fuel energy and resulted in the emergence of a fossil-fuel dependent society.

Now is the time to use infrastructure to privilege new energy supplies. Just as most of the nation's coal, oil, and hydroelectricity sites are located far away from consumption centers, so are many of the most promising wind and solar power sites. We have the technical potential to derive large energy supplies from wind sites in the Great Plains or solar farms in the Southwest but lack mechanisms to transport the power to consumers. Investing in new transmission wires could make the development of these sustainable resources practical.

Ultimately, the mineral economy will end, whether we plan carefully for this inevitability or bury our heads in the sand. Planning requires hard work, some sacrifice, and changes in how we live. On the other hand, it offers clear benefits in the potential for a sustainable energy system and the preservation of planetary resources that support human life, as well as the millions of other species that also occupy the earth. Taking the path of least resistance is easier, but the crash will be much harder. As I have shown throughout this work, the mineral economy was not inevitable; it was shaped by human efforts. Those same efforts are now needed to create a more sustainable and planet-friendly energy system capable of supporting human life for generations to come.

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